Thesis.

'A Study of the Vegetation of Hill Grazings in Relation to Physical Factors, in Selected Areas of Southern Scotland.'

by

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CONTENTS.

Preface.

The idea of undertaking an explanatory, geographical study of the vegetation of the hill grazings of the Southern Uplands of Scotland was originally inspired by the late Professor A.G. Ogilvie O.B.E. M.A.B.Sc.(Professor of Geography. Edinburgh University.1931-54.). The author therefore regrets that she must record in retrospect the considerable debt of gratitude she owes to his advice and, above all, encouragement throughout his supervision of this thesis. To Professor S.J.Watson. M.Sc. D.Sc. F.R.I.C. (Professor of Agriculture and Rural Economy. Edinburgh University.) grateful acknowledgement is made for the help and constructive criticism given in the course of his supervision, and particularly during the final stages, of this work. Of the many who gave unstintingly of their time and advice, and whose help facilitated her field work, the author would like to express her gratitude to Professor Braid, Dr. E. Wyllie Fenton, Professor R. Miller, Mr. I. Mitchell (Agric.Advisor.. Kirkcudbrightshire) and Mr. Browne (Forestry Commission.), to those many farmers and shepherds in all three areas, without whose local knowledge and generous hospitality these surveys in isolated regions would not have been possible, and to the Carnegie Trust for a generous grant towards field expenses.

GLOSSARY.

Agrostis spp.	bent grasses
Aira/Deschampsia flexuosa	wavy hair grass
Anthoxanthum odoratum	sweet vernal grass
Bellis perennis	daisy
Blechnum spicant	hard fern
Calluna vulgaris	common heather or ling
Carex spp.	sedges
C. spicata	prickly sedge
Campanula rotundi-folia	harebell
Cladonia rangifera	reindeer moss
Deschampsia caespitosus	tufted hair or tussock grass
Empetrum nigrum	crowberry
Erica cinerea	bell heather
E. tetralix	cross leaved heather
Eriophorum angustifolium	common cotton grass or sedge
E. vaginatum	sheathing cotton grass or sedge, bog cotton or draw moss
Festuca ovina	sheep's fescue
Galium saxatile	heath bedstraw
Helianthemum Chamaecistus	common rock rose
Holcus lanatus	Yorkshire fog
Hypnum scheberi	Hypnum moss
Juncus articulatus	jointed rush: spret or sprat
* J. communis	common rush
Luzula sylvatica	great wood rush
Lycopodium selago	fir club moss
Molinia caerulea	purple moor grass: flying bent
Myrica gale	bog-myrtle: sweet gale
Nardus stricta	moor mat grass: white bent
Narthecium ossifragum	bog asphodel
Polygala vulgaris	milk wort
Polytrichum commune	Polytrichum moss
Potentilla erecta	tormentil
Pteridium aquilinum	bracken fern
Rhacomitrium lanuginosum	woolly hair moss
Rubus chamaemorus	cloudberry
Rumex acetosella	sheep's sorrel
Scirpus caespitosus	deer-sedge or -grass
Seiglingia/Triodia decumbens	heath grass or decumbent triodia
Sphagnum spp.	bog moss
Thymus vulgaris	wild thyme
Trifolium repens	white or Dutch glover
Ulex europeaus	gorse, furze, or whin
Vaccinium myrtillus	bilberry or blae'berry
V. Vitis-idaea	red wortleberry or cowberry
Viola tricolor	heartsease or pansy
* Juncus squarrosus	heath or bog rush

<u>Frequency Symbols</u>
used in the following text:

d...............dominant.

co-d............co-dominant.

a...............abundant.

f...............frequent.

o...............occasional.

l...............local.

r...............rare.

v...............very (prefix to above).

Diagrams in the Text.

OTHER MAPS, DIAGRAMS, and PHOTOGRAPHIC ILLUSTRATIONS

are contained in the accompanying MAP FOLDER, and reference to them in the text is indicated by the symbol..F.1. F.2 ,and so on.

SECTION I

INTRODUCTION.

CHAPTER I

The Problem and its Setting.

Writing at the beginning of the century on the Botanical Survey of Scotland[1] that he and his brother had initiated, William Smith pauses for a moment to reflect on the transition, the change of emphasis, that was taking place at that time among botanists interested in plant geography, from the study of plant distribution (floristic species per se) to the study of plant communities in relation to their environment (ecology). He was but one of that group of early pioneer workers who were in the process of not only formulating but applying the recently conceived concepts on the communal and dynamic nature of vegetation to various areas of the British Isles and were laying the foundations of the modern science of plant ecology - a science to-day in the forefront of agricultural and forestry research. To them we owe above all those regional studies of British vegetation[2] and surveys, such as, to mention but a few, those of Robert and William Smith,[3] [4] Hardy[5] and Crampton[6] in Scotland, often supplemented by medium scale vegetation maps.

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1 Smith, W. G. (1902a) pp. 133-34.

2 Tansley, A. G. (1911).

3 Smith, R. (1900).

4 Smith, W. G. (1904-5).

5 Hardy, Marcel (1905)

6 Crampton, C. B. (1911)

They not only recognised and defined distinct vegetation communities and associations and the environmental conditions under which these occurred but they were able, on the basis of the often wide areas covered, to deduce general assessments as to the effect of soil (and related geological formations), altitude, configurations of the land surface and regional climatic conditions in determining the particular associations and in accounting for the differences in the vegetation pattern from one area to another. The fact that they were not at first perhaps fully appreciative of the importance of the part that biotic in contrast to physical factors played in determining the type of vegetation in any particular area, and that, as explorers in this new branch of the natural sciences, they lacked detailed information about the factors of the environment and about the individual species within it does not minimise the value of their work.

It was however inevitable that as the complexities of the 'habitats' occupied by the various groups of plants became more apparent and as the need to know more precisely and more accurately what were the exact relationships between plant associations and their environments, the requirements, composition and significance of the individual species, and the nature and behaviour of each habitat factor, that the energies of plant ecologists should become concentrated on specialised studies, in ever increasing detail and intensity, of smaller areas and of individual factors and aspects. Indeed Robert and William Smith regarded their broad surveys as merely the preliminary stages to the detailed analysis of much smaller areas. But it is perhaps to be regretted that their regional surveys were not continued and maintained at the same time. Comparable surveys since 1913 have been few and limited, and their place has been taken by such even wider surveys as the Grassland Survey of England and Wales[1] and the Land Utilisation Survey of Britain[2] with their greater emphasis on the agricultural potentialities and utilisation of the land.

From the wealth of detailed information on all aspects of plant ecology gleaned from a wide range of sources which has been amassed since the beginning of the century (and which has further been collected and presented in relation to the regional setting of the physical and historical background of the British Isles by Tansley[3]) two important facts emerge which are probably paramount in an understanding of the unimproved and uncultivated - the semi-natural in vegetation of Britain and, in particular, of the vegetation of the moorland hill grazings of Scotland. The first and most important is that a large proportion, if not all, of this vegetation below altitudes of 2000'-2500', or even 3000',

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1 Stapeldon, R. G. and Davis, W. (1936)

2 Stamp, L. D. (Director) Land Utilisation Survey of Britain.

3 Tansley, A. G. (1949a).

has been derived from the formerly existing primitive (climax) types of vegetation by means either of its complete destruction or its considerable modification by the continuous actions of man and his grazing animals throughout historical times. This primitive vegetation determined largely by conditions of soil, climate, altitude and exposure was probably[1], below the limit of the treeless Arctic-Alpine scrubs and heaths, at 2000'-2500', composed of either oakwood with birch, on good soils and more frequently at altitudes below a 1000', and pine-woods with birch on poorer soils and within an altitudinal zone above the oakwoods with heather and bog mosses on those localities where soil and drainage or climatic conditions were inimical to tree growth. The destruction or modification of this primary natural vegetation cover, while essentially a continuous and cumulative process, can nevertheless in Scotland be associated with, and intimately related to, two distinct phases in the economic and indeed political history of the upland and highland areas.

The first[2] witnessed the gradual but increasingly rapid destruction and clearance of the primaeval woodlands and forests, attendant upon the increase of population from pre-historic times up to the beginning of the eighteenth century, for arable agricultural land, for domestic and industrial fuel and by the

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1 Fenton, E.W. (1937 a).

2 Fairhurst, H. (1939)

depredations of wars, rebellions and Border raids which are a constant theme in the history of the Southern Uplands and the Highlands of Scotland. The draining and cutting of both upland and lowland mosses, and the utilisation of the uncultivated hill areas for the common pasturage of cattle and sheep served to maintain and to extend a treeless moorland vegetation climax and to successfully prevent the regeneration of woodland. The second phase[1], initiated largely in the first half of the eighteenth century and heralded by the introduction of large-scale sheep farming and the concurrent and largely forcible depopulation of highland areas, is characterised by the degeneration of the, by then, well established moorland sub-climax, under the onslaught of intensely concentrated and selective sheep grazing - a process (which reached its peak in 1870 but) which has continued unchecked, though subjected to marked fluctuations in time and space, to the present day particularly within those two most densely sheep populated areas the Central Highlands and the Southern Uplands. The drastically selective and 'extractive' nature of this 'monopolistic' land-use has resulted in a deterioration of the vegetation, evidenced primarily by the suppression and destruction of heather moorland and its gradual replacement by a Nardus dominated grassland which has all but reached a biotic climax in many instances and has, in unfavourable conditions, resulted in accelerated soil wastage and erosion.

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[1] Fenton, E.W. (1937 a)
Fenton, E.W. (1937 b)

This has been accompanied by a virulent spread of bracken, its growth no longer checked by the regular cutting and the heavy trampling of cattle to which it was subjected when the hill areas not only supported a larger population but carried a more mixed (and less selective) type of grazing. The more recent history - since the end of the nineteenth Century - has been one of increasing concentration on the most favourable areas and the abandonment especially in the highlands of the poor, more remote, higher regions to either grouse-moors or deer-forests but where often neglected management has consequently reduced the grazing value of the moorland vegetation. While sheep farming is a relatively recent introduction into the Highlands it has, however, been typical of the Southern Counties of Scotland probably for many centuries; bald and treeless with often a higher percentage of grass than heather, their lower altitudes and relative accessibility have presented no serious deterrent to the complete utilisation of the Southern Uplands as grazing grounds and the effects of intense sheep grazing are hence probably more pronounced and widespread than further north.

The second important fact that has emerged from the ecological researches of the last fifty years is that since the initiation of a vegetation cover in post-glacial times, climatic conditions in Britain, as revealed by the variations in the composition of pollen and plant remains preserved in the peat deposits which have accumulated since then, have undergone several well marked fluctuations, accompanied by concurrent alterations in the composition and character of the climax vegetation. Further, there are indications, albeit slight, that there may be what Tansley calls a "tendency towards increasing dryness of climate at the present time"[1]

While the character of the vegetation cover of the upland moorland areas of Britain and the nature of its development are more clearly appreciated many problems still remain unsolved as to the particular conditions affecting both plant growth and the changes that have and are still taking place. The difficulty of their solution is aggravated by the fact that, whereas a fairly comprehensive picture of the development of vegetation from post-glacial to early prehistoric times can be reconstructed, there are no comparably detailed records presented by either man or nature within the more recent historical period and it is, for the most part, virtually impossible to estimate exactly the number and relative intensity of the factors which have influenced a particular region and what changes the vegetation may have undergone in the recent past. It is indeed doubtful whether there is very much of the hill grazings of Scotland which can be considered as a perfect example of a biotic or sub-climax - a term which implies a vegetation in a state of equilibrium or stability in relation to both physical and biotic factors - but rather in view of the considerable variations in the intensity of such biotic factors as burning, grazing,

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[1] Tansley, A. G. (1949a) p. 169.

draining etc., which have taken place in the past and are still effective, added to the possibility of a climatic change most of the moorland areas must be regarded rather as essentially transitional in character.

These problems have quite recently assumed a more than purely academic interest. The vital economic necessity finally imposed by the last war to lessen Britain's dangerous over-dependence on imported food, to increase her own production and to utilise to the maximum the potentialities of her land has turned attention to and has quickened an interest in that large block of rough hill grazings which represent 33% of her total surface; indeed in Scotland, in 1939, of a total acreage of 19,069,000 acres, 10,465,016 acres - practically 60% - were returned as rough grazing, a proportion which varied within the Southern Uplands from 50% in Lanarkshire to 67% and 78% in Kirkcudbrightshire and Peeblesshire respectively.[1] The bulk of these rough grazings lie over 800'-1000', above the limit of not just economic but possible arable farming. Harsh climatic conditions, poor soils, together with an often considerable isolation have imposed on these areas a uniformity and monopoly of agricultural use, as breeding and rearing grounds for hardy animals, with the emphasis during the last two hundred years on sheep. This monopoly - an essentially 'extractive' type of farming - has, as already indicated, taken its toll of the natural

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[1] Stamp, Dudley L. (1950) pp. 196,199,480.

fertility of the hill-grazings and further, as such, it provides the farmer with little margin of adaptibility in the face of climatic conditions which may, and often do in fact, spell disaster on an average of once in every four or five years and the back breaking competition from cheap imported wool and meat. Indeed the story of hill sheep farming from about 1870 onwards, with the exception of one or two short lived revivals, has been that of gradual decline in face of adverse economic conditions - which resulted in a few instances in gross over-stocking, but more frequently in a serious deterioration in the management and consequent condition of the hill-grazings. The interests of grouse shooting frequently superceded those of sheep, and it was during this period, and particularly between the two World wars, that farmers and landowners abandoned the unequal struggle and the Forestry Commission acquired much of its present holdings. The general decline was further accompanied, and indeed aggravated, by a serious decline in the population of these already sparsely populated areas.

The prospect which met the eyes of those who turned perhaps hopefully to the hill-grazings in 1939 was far from cheerful - as the Committee on Hill Sheep Farming in Scotland observed, "just prior to the outbreak of war there was growing concern that hill sheep farming was in serious economic danger"[1]. It

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[1] Department of Agriculture for Scotland (1944).

was no less apparent to the members of this committee that if the health of this important branch of Britain's agriculture was to be improved and maintained and if its contribution of meat to the nation's larder was to be increased, one of the first tasks would have to be an effort, however difficult and arduous, to repair the depredations of the last two hundred years and to restore the fertility, to improve the grazing value and to increase the carrying capacity of the hill-grazings. It is a task which further demands a priori an intimate knowledge of the nature of hill plant species and the conditions under which they develop. Since the last war sheep farming has, under the stimulus of attractive and assured prices, a constant demand and government subsidies, undergone an amazingly rapid resuscitation. The task of long term improvements in the actual conditions of the hill land must of necessity be a longer and slower one, dependent (in many instances) on the results of fundamental research and experiment. Much has been done in this direction, "but, there is still much", as Fenton says, "to be done in the general physiology and the conditions affecting the plants constituting the chief vegetation of hill-grazings from about 800' to higher levels"[1]. One however of the most pertinent and interesting features which has emerged from recent work on the nature and development of hill-grazings is the ever increasing emphasis that workers have tended to place on the part played

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1 Fenton, E.W. (1951a).p. 34

by physical factors (climate, landform, aspect, exposure etc.) in determining the effect of the influence of man's utilisation and management on the vegetation of hill-grazings. For instance Fenton, who has carried out exhaustive and detailed ecological studies of the hill-grazings of south-east and mid-central Scotland in relation to biotic factors reiterates that, "in hill-grazing areas climatic conditions, elevation, slope, aspect, soil conditions and biotic factors all play an important part in determining the nature of the vegetation"[1]. Also Pearsall[2], with reference to the Pennines and other areas, illustrates that while the moorland and bog vegetations owe something of their specific character to changes in the vegetation arising from either biotic factors or climatic changes, many of their most characteristic and striking features are associated with the landforms over which they occur. It is perhaps not too much to say that the biotic factors may be considered to work within a regional framework in which their effects are largely determined by geology and landform, altitude and climate. To a very great extent the interest in this aspect, among the many problems presented by the hill-grazings of Scotland, has motivated this present study.

The primary objective here, has been, within that region known as the Southern Uplands of Scotland (and for which, apart

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1 Fenton, E.W. (1951a).p. 55

2 Pearsall, W.H.(1950) pp. 163-181.

from the Moorfoot hills, no detailed map of the vegetation exists) to attempt to assess, on the basis of a reconnaissance survey, the principal characteristics of the vegetation of its hill-grazings and to determine how far they could be related to or explained in terms of the principal physical features of this region. It was obvious however that to cover the whole of the Southern Uplands, even on the basis of a reconnaissance survey in a strictly limited period of time, was beyond the capacity of the individual worker. It was therefore decided to base the survey on three sample areas - areas chosen with a view to providing as comprehensive a cross section of the Southern Uplands as possible.

Fundamentally the Southern Uplands - a title which embraces that tract of continuously hilly uplands (generally over 1000') which straddles the South of Scotland from St. Abb's Head in the east to Finart Point in the west - forms a well defined physical region which derives its considerable measure of unity from the general and broad uniformity of its geological and landform features. The complexly folded structure, the predominance of Lower Palaeozoic Ordovician and Silurian greywacke and the north east - south west Caledonian strike are maintained throughout its extent. Only in the south west is the uniformity of its geological composition and structure interrupted by the massive granitic intrusions of Kirkcudbrightshire and the outliers of younger sedimentary rocks in Nithsdale and Annandale. Further, over 1000', apart from peat caps, superficial deposits of any depth are negligible in amount and extent and the bare bones of the underlying rock are never far from the surface.

To no less degree in its peculiarly distinctive scenery does the Southern Uplands maintain what Geikie describes as, "a uniformity and even monotony throughout its whole extent"[1]. Its landform features are those of a high, broad, maturely dissected plateau or table-land of marked relief. It has been reduced, by the deep steep-sided valleys which dissect it, into a series of flat-topped or convexly-domed ridges and hills of varying width which reveal a well marked uniformity of summit level between 1500'/1750' - 2000' and above which isolated summits and ridges rise, particularly in the centre and the south west, to a maximum altitude of approximately 2,700'. The Southern Upland Boundary Fault provides a definite and continuous geological boundary to the north and coincides in some instances, especially towards the north-east, with an often sharp topographical break between the Uplands, and the Central Lowlands to the north. Its southern boundary is less well defined and the plateau-like surfaces decrease gradually in altitude in this direction and merge finally into the lowlands of the Merse of Berwick and of south and south western Galloway.

Contrasts and variations of relief within this regional unit arise largely and primarily from the varying degrees of intensity in its dissection and erosion. One of the most

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[1] Geikie, A. (1901) p. 315.

clearly defined and striking contrasts occurs as between those parts of the Southern Uplands lying south-west and north-east respectively of the River Nith. In the former the greater degree of dissection and the greater geological variety have been further emphasised by very considerable glacial erosion with wide over-deepened valleys, innumerable lakes, ridged and mammilated ice-scraped and ice-plucked surfaces and slopes, it presents a wildness and ruggedness of scenery that appears to have little in common with the Eastern Southern Uplands. Only the uniformity of elevation and general smoothness of form of those flat-topped summit remnants relates it to the east, where deep, narrow valleys, smooth, convexly curved steep valley side-slopes and often broad flat or gently sloping plateau-like hills and ridges prevail. It is not without reason that the south western Southern Uplands have been compared with the north west Highlands and the eastern Southern Uplands with the Grampians.

This contrast in scenery is further reinforced by a well marked difference in regional climates as between the south west and the north east, which reveals itself in the high rainfall amount and atmospheric humidity and in the mild winter temperatures of the south west as against the drier conditions and more extreme temperatures of the east and north east and, although the high and increasing altitudes of the upland areas may modify, by increasing rainfall and lowering temperatures, the strength of the contrast between these regional climatės, whose characteristics have generally to be assessed on the basis of lowland (less than 500') meteorological stations, - they are nevertheless maintained in the uplands of the south west and north east to no uncertain extent.

The final decision therefore as to the position within the Southern Uplands of the three sample areas to be surveyed was largely dictated not only by the necessity to incorporate the two contrasting types of relief but to provide as characteristic a "cross-section" of the more gradual climatic change as from south west to north east as possible. With these requirements in mind, three compact and as well defined as possible blocks of moorland, each with a comparable range of altitude (from 750' to at least 2000') were selected from the south west, the centre and the north east of the Southern Uplands respectively. (see F.1.)

Each individual sample area, named from adjacent settlements, in order -

1) The Newton Stewart Area - south west.
2) The Wanlockhead Area - north centre.
3) The Peebles Area - north east.

covers approximately a hundred square miles. Their exact position was chosen (since means of transport were restricted to bicycle and foot) largely to allow a reasonable degree of accessibility and the exact extent by the occurrence of reasonable well defined natural boundaries, primarily river valleys.

Within each area the character of the moorland vegetation and its relation to the particular physical features was studied and surveyed as thoroughly as time allowed.[1] In presenting the results of this study each sample area will be first analysed individually and will be treated as a more or less self contained unit and only a brief and but general suggestion of the contrasts between the three will be made in passing from one to another. Each analysis will be concerned <u>primarily</u> with a discussion of the vegetation of the moorland hill-grazings in relation <u>particularly</u> to the characteristic landform features of the area in question. It will be appreciated that in view of the scarcity, indeed in many instances the virtual absence, of any reliable long term meteorological records for areas over 500' the effect of climate, either regional or local, within the limits of these relatively small areas can only be assessed in the broadest of terms. However in the general geographical introduction that prefaces the analysis of each area, the principal climatic characteristics, as far as it is possible to assess them from available data, will be outlined - together with a brief description of the general landform and land utilisation features of the area. The amount of emphasis given in the geographical introduction to the latter aspect will vary from one area to another and will depend largely on how far it affects 1) the upper limits of

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1 The problems and procedure of the field work will be discussed in Chapter II.

cultivation and hence the lower margin of the unimproved hill-grazings and 2) the character and utilisation of the hill-grazings themselves.

The following more detailed analysis of the vegetation within each area aims primarily at;

1) describing the types of vegetation - the associations - their characteristic composition (specific), their associated type of soil, their form and colour, their utilisation and the variations that occur within each.

2) Outlining the characteristics of the distribution of each association within the area.

3) Assessing to what extent the distributional characteristics can be related to particular landform features within each area and how far any particular landform may have determined or have controlled the modification by biotic factors of the particular type of vegetation or association.

4) Considering each association in the light of more intensive, detailed, and relevant ecological work that has been undertaken by other workers on particular species or similar types of vegetation in Scotland - in an effort not only to assess the relationship of one association to another, and their possible status, but in order to assess how far it has been justifiable to recognise individual associations and further relate them to particular sites.

The final section of this study will be devoted to a comparative review of the three areas surveyed in an effort to analyse the principal and most significant differences revealed by them - differences which to a limited degree may be considered representative of the Southern Uplands as a whole - and to assess to what extent such differences as occur may be related to contrasting climatic or even landform conditions. It is felt that only in the course of such a comparison can any useful conclusions be suggested as to the possible effects of climate on vegetation and an attempt has accordingly been made to deduce from available climatic and meteorological data conditions at given altitudes (e.g. 1000',1500',2000') in each area which will provide a quantitative, albeit arbitary, basis for a comparison of the climate of these three essentially upland areas.

In conclusion it might be said that this study is offered not so much as a detailed ecological analysis as a geogra phical review of the 'regional' distribution of vegetation in the Southern Uplands considered in the light of the detailed and intensive ecological studies and researches which have accumulated and evolved since Robert and William Smith first initiated their Botanical Survey of Scotland. To this is added an attempt to assess how far the vegetation may vary throughout the extent of the Southern Uplands and to what these variations may be ascribed.

To the ecologist who feels that the broad regional surveys of vegetation have now outlived any useful purpose this may appear a retrogressive step or at most an academic exercise, but he might pause to consider that they provide a 'framework', all too infrequent at present, within which correlations between more detailed discoveries and researches from widely spaced and 'micro'-areas could be usefully attempted - correlations of immense practical value to the forester, the applied agriculturalists and to the geographer, each of whom often wishes and needs to apply such findings and hypotheses to his own particular region or area. Also the writer sincerely believes that from their very regional approach such surveys might assist in the understanding of the part played by physical factors in determining the effects produced on our hill-grazings by uncontrolled biotic factors.

This study was undertaken in a full realisation of the complexities of the problems involved - it hopes to present what might perhaps be called a geographical and regional 'recapitulation' of the vegetation of the Southern Uplands; but in view of the many still unsolved problems presented by moorland vegetation it is inevitable that as many questions should be raised as answered.

CHAPTER II

Methods of Surveying and Mapping Vegetation.

Since one of the principal and indeed basic objectives of this work was to study and explain the distribution of the various types of vegetation within each of the sample areas, it was considered necessary that the field work should be conducted along the lines of as systematic a survey as possible and should be undertaken with a view to finally representing on a map the distribution of major and well defined plant communities. Only by such means could characteristic distributions be satisfactorily recorded and the spatial relationships of one community to another be clearly illustrated. It was therefore decided to attempt a Primary Survey[1] along those lines first initiated by Robert and William Smith and which, as defined by Tansley would, "aim at representing on a medium scale (map) the whole of the vegetation of a region".[2] However, the actual methods of study and survey employed in this instance, while based very largely on Tansley's conception of a Primary Survey, were adapted and modified to meet the exigencies of two factors - first, the strictly limited amount of time that the writer was able to spend in the 'field' and second, the often difficult terrain of these essentially upland areas.

Field Work: Approximately two months were spent in each of the three areas, during which periods the writer "lived on the spot",

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1 Tansley, A.G. (1946) pp. 91-105

2 Tansley, A.G. and Chipp, T.F. (1926) p. 42

but the actual amount of time devoted to a study of the vegetation on the ground was curtailed even further by the exasperating frequency of hill mist, especially in the Newton Stewart and Wanlockhead areas. Also these two particular areas were too remote and too isolated to be visited on those odd occasions when weather conditions would have been more favourable and the maximum use could have been made of the time spent in the field. The period of the year during which field work was undertaken extended from May to September but again, there was too little time to attempt a study of each area and its plant communities under different seasonal conditions. Indeed in some instances part of an area had to be covered in spring, while the remainder was inspected in full summer or autumn. Spring and autumn certainly provide advantages in the often greater colour contrasts presented at these times of the year by the various plant communities - a factor which is of considerable value in facilitating the mapping of vegetation boundaries and limits. The identification of individual species and the assessment of the proportional specific content of any community is however not so easy as in mid-summer. Also, only in the case of Newton Stewart was an effort made to re-visit the area; and in this instance a rapid review of the vegetation was necessitated, indeed made imperative by the peculiar difficulties and problems of classification raised by this more complex region.

The limits set by time meant that the luxury of undertaking a preliminary reconnaissance survey (which should and would normally precede a Primary Survey), with a view to assessing the salient features of the vegetation and to deciding the principal communities that could be mapped had to be foregone. Instead reconnaissance and survey were combined. Even line surveying whereby reconnaissance and primary survey could be more satisfactorily combined had also to be abandoned. Line surveying - even when the survey lines are very closely spaced - is more suitable when the production of a vegetation map is the main end in view but is not considered a really satisfactory method of studying physical factors and the relation of vegetation communities to such; also, there is the added difficulty of undertaking and completing reasonable parallel traverses in hilly country where means of communication and transport are limited.

The general procedure adopted throughout all three areas was in the preliminary examination of the particular area from topographic (usually O.S. 1:63360) and geological (1:63360 Geol., Survey Solid and Drift eds.) maps, to divide the area up into a number of 'blocks' of country, often although not always comprising a burn and its watersheds which, allowing for the distance away from base, could be conveniently covered - 'walked over' - in the course of a day's work. The aim of the field work was then to assess the nature and distribution of the principal type, or types, of vegetation within each 'compartment', together with as much relevant information about the physical and biotic factors of their habitats as possible. Within the different types of vegetation - differences often betrayed in the first instance by colour and form - an analysis was made of the specific composition, and any other relevant or significant characteristics and, as far as possible, the extent of that particular type of vegetation within the compartment in question was estimated. The analyses, which had of necessity to be very much in the nature of random samples, were directed <u>not</u> at providing detailed and exhaustive botanical lists but rather at determining those dominant and most abundant species (and their form) which occurred most frequently and their relative proportions, within a given community. The method of sampling, however, was at random only in so far as it was not planned systematically in advance but it did nevertheless endeavour to assess the principal variations which occurred within any one community. Notes were also made concurrently on the relations of a particular type of vegetation to altitude, general slope characteristics, aspect, exposure etc., and on the evidence of any natural or artifical modifications of the vegetations that had or were in the process of taking place. An attempt was also made to assess general soil characteristics <u>but</u> only in so far as depth, consistency, and drainage conditions were concerned. Somewhat over-ambitious plans to define and record systematically the limits of plant communities by means of aneroid barometre and prismatic compass readings, and to take soil samples and slope measurements within each, had very early to be abandoned. Not only was such a procedure too slow, and the sheer physical effort of carrying an over-abundance of equipment in hilly country too restrictive, but it soon became more than obvious that the time for such detailed measurements and recordings could only be after the completion of an initial survey.

Equipment was therefore very soon reduced to a field-map and a note book and methods to those of a purely observational nature. The nature of the vegetation and, where visible, well marked boundaries between one type of vegetation and another were roughly indicated by means of convenient symbols on the field map. In both the Newton Stewart and Wanlockhead areas field mapping had of necessity to be done on 1:63360 maps - since without the basis of a reconnaissance survey and in view of the nature of the work there was little virtue in confusing the issue by endeavouring to cover the ground with a multiplicity of 1:10,560 sheets. Only in the Peebles area were 1:25,000 Provisional O. S. maps available at the time of survey[1], and such sheets used in conjunction with the 1:63360 map of the district greatly facilitated the recording of vegetation in the field in this particular area. One of their principal advantages lies

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1 1:25,000 G.S.G.S. sheets had been produced but were out of print and not available for field work - however they would have been of little use in this respect since as straight photographic reductions of existing 1:10,560 sheets they are often confused, blurred and badly printed and with too much detail. They were used only to construct contoured base maps for final plotting.

in their representation of field boundaries and all march-dykes - invaluable guide lines in the plotting of the limits or extent of particular communities. Their only disadvantage as far as large scale surveying is concerned is that their scale and admirable clarity in the representation of land form features lead to a temptation to record excessive and not always absolutely necessary detail.

By and large, it was eventually found that the most satisfactory procedure in the course of a day's work was to traverse the particular 'block' or 'compartment' of country under consideration along a generally pre-determined line (with frequent and often wide digressions to each side of this line but always returning to its approximate course) from the lowest to the highest point, taking samples en route. Then, particularly as work advanced and a greater familiarity with the composition, appearance and colour of the principal types of vegetation within each of the areas was acquired, a fairly accurate assessment of the distribution of plant communities within the particular 'compartment' covered could be gained from a suitably placed and usually high vantage point and could be sketched in on the field map. The return journey could then be devoted to those areas of slopes obscured from view in the first traverse, to re-checking the nature of the vegetation already inspected or to merely confining ones attention to particular or significant physical (landform) factors. However methods and procedure had constantly to be adapted and modified in the face of varying relief and vegetation features and similarly the speed of surveying vacillitated constantly with ground conditions and with the stage of survey. It is obvious however that in any type of survey which depends solely on observational methods no infallible set of rules as to exact procedure can be satisfactorily produced and rigidly adhered to. Much depends on personal and therefore essentially arbitary judgements and the attainment of a reasonable degree of uniformity and standardisation in a survey of a wide area can best be sought and achieved by endeavouring to keep constantly in mind the primary objective of the field work and to relate interesting and relevant detail to, without allowing it to confuse, the main issue.

Classification: As work progressed in any one area, the broad outlines of the main types of vegetation - the distinct communities - the characteristics of their distribution and the general features of their habitats began to emerge from the, at first seemingly inexplicable and random, pattern of vegetation types and facets dependent upon a complex of physical and biotic factors. The next problem therefore was how to reconcile the often complexly detailed pattern of vegetation observed on the ground with the broader and more widespread distribution of a few general plant communities - to decide exactly how best to classify, define and delimit the vegetation of a particular area into plant communities which would allow and provide a logical grouping of many variations, which would illustrate most vividly the most important relationships of vegetation to land form and which, at the same time, could be reasonably and clearly represented on a base map of scale 1:25,000 but which would eventually have to be reduced to approximately 1:63,360. It is a problem with which all prospective mappers of vegetation must come to grips - a problem whose implications can best be summarised in Tansley's lucid statement that "communities which have been shown separately on field maps will have to be combined for representation on a published map of reduced scale. Seral and sub-seral phases and smaller areas which have been modified by man but which are obviously related to certain climax associations will in general have to be included under the same head as the climax unless they are very extensive. Parallel climaxes which have no obviously different habitats and represent either different consociations of one association or sometimes parallel associations must often be treated in the same way. To decide how exactly the various communities should be grouped is often a difficult task, and ability to construct a really natural grouping depends on a thorough understanding of the history and nature of the vegetation, which can often only be gained by prolonged study. The effort to make a natural grouping is very beneficial because it directs attention to important unsolved problems which further study may elucidate".[1] Further it is a problem whose final resolution will in any particular instant depend on the nature of the field survey, the scale of the proposed reproduction and, to no less extent, upon the ultimate purpose of the completed map.

In the case of this particular survey, the fundamental and basic distinction is that made between wet and dry moorland communities, whose classification is dependent purely and simply on:-

1) the relative dominance of species typically and usually indicative of either wet or dry <u>soil</u> conditions and/or
2) the depth, moisture content and drainage conditions of the underlying soil, which is frequently in these moorland areas peat or of a peaty nature.

Often the distinction between these two types tends to be a relatively clear cut, well defined and easily recognised one. Nevertheless there are frequently occasions where wide areas are occupied by a mixture of wet and dry species in such proportions that it is often difficult or impossible to assign them to either one or another of these major communities. Also, and indeed often more frequently, a community dominated by species characteristically intermediate or "marginal" in their moisture tolerance occur on peat or peaty soils which in depth and moisture content are intermediate between those of the more

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1 Tansley, A.G. and Chipp, T.F. (1926) p.44

typically wet or dry moorlands. Such conditions necessitate the recognition and definition of intermediate communities, whose very nature makes them difficult to define and even more difficult to delimit.

Each of these broad basic communities has been divided further into a number of consociations or associations classified primarily on the basis of a combination of factors which are, in order of importance:-

1) the dominance of one, or a characterisitc combination of two or more, typical moorland plant species, and frequently accompanied by one or sometimes more "characteristic" species which may attain abundance but are rarely dominant.
2) a usually distinctive and characteristic colour imparted by the particular combination of species in any association or consociation.
3) a well defined physical (most usually in this instance 'defined' in terms of land-form) habitat.
4) occasionally (but not invariably) a characteristic depth, texture or moisture content of an associated soil.

The classification has, in the case of practically every particular and named association throughout all three areas, been made primarily on the basis of botanical (specific) composition. However it cannot be too strongly stressed and emphasised that it was not always found possible to adhere strictly and consistently to this method of classification. In some instances the nature of the land surface is such that a number of different and often very distinct associations occupying relatively small areas occur in close juxtaposition. As each cannot be represented individually on a medium scale map they must be 'lumped' into a composite association whose classification is hence, under such circumstances, often basically dependent upon a particular land form. In yet other cases while the grounds for recognising an association on the basis of either botanical content or physical habitat alone may be slender, the imprint of biotic factors is often too striking to be ignored and is further often distinctive enough to justify the classification of a separate association. It is felt that since classification must in any case be an arbitary procedure at this stage and since it has been attempted not for its own sake but as a means to an end, there is ample justification for the use of more than one dominant criterion on which to base the classification of any particular consociation or association.

In any of the three sample areas the associations within any one of the three principal communities wet, intermediate or dry, are often very closely related and indeed under similar habitat conditions interchangable, hence there occur frequently mixtures of two associations which over other areas are separate and distinct - as for example dry heather and dry grass moorland. It is often difficult to decide to which association such mixtures should be assigned. Again, it is a matter of personal judgement based on broad overall impressions, though where the mixture is an even one a compromise has been reached by indicating it as a mixed association. Also, it will be obvious in the detailed discussion of each sample area that follows that most of the so-called associations are seral stages rather than true climaxes or even sub-climaxes and that, in addition many should be designated as consociations rather than as associations. However, largely for the sake of simplicity, the latter term has been used throughout the following discussion of the vegetation for the particular groups of plants whether they are dominated by one or more species and whether they are true associations (in the strictly botanical sense of the word) or not. In the detailed analyses of each area the particular nature of each association, its composition, its possible status and the basis of its classification will be explained. There is perhaps a case for the definition and description of the associations recognised being stated preliminary to the analysis of their distributions in each of the three sample areas. However, since each association does not necessarily occur throughout all three and since any one particular association may reveal slight differences within each of the three areas, it was considered more advisable and useful to treat each fully in its particular regional setting.

The representation on a map of the various associations into which the vegetation was finally classified depended primarily on the areal extent of each over the ground. Patches too small to allow reasonable ease of illustration had to be ignored, for instance, local patches of wet moorland within areas otherwise completely dominated by a dry vegetation or vice versa, were overlooked unless of particular significance. The actual definition of the limits - the boundaries - of the associations to be shown on the map presented yet another problem. Well and clearly-marked sharp boundaries on the ground between two different and adjacent associations are relatively infrequent. They are most frequently and usually associated with a well defined topographical boundary or 'break', especially those dependent upon a sharp change in slope gradient. In such instances the physical nature of the ground surface provided a useful guide in the definition of the extent of a particular association on the map. In yet other instances associations revealed certain comparatively well defined altitudinal limits or ranges, in which case selected contour lines could be reasonably used to define their limits - unless field work had revealed any striking divergencies. However, over much of the areas under consideration nature does not provide continuously well marked boundary lines and particularly, as between the associations of either the dry or wet moorlands respectively, the transition from one to another is more often by way of a <u>transitional zone</u> of varying width whose representation with any accuracy on a medium scale map is rarely easy - if not impossible - to indicate.

Aerial Photographs: As a final resumé of field work preliminary to constructing a vegetation map and as a complementary aid to plotting associations and their limits, aerial photographs can be of some, albeit limited, value. But considerable caution must be exercised in their use and in general they can only be interpreted successfully and satisfactorily after a familiarity with the types of vegetation over any particular piece of ground has first been acquired.[1] When this has been accomplished it is often possible to identify a particular association or type of vegetation on the aerial photograph and to discern its limits approximately. However, clearly marked boundaries only appear on the photographs when they are similarly defined on the ground - and then, only if light conditions and the form of the vegetation (its length, density etc.) are such as to produce striking tone or shade contrasts on black and white photographs. The principal advantage gained in this respect from an inspection of aerial photographs is that they provide a general over-all view of the extent of such boundaries which is not always easy to see or trace accurately on the ground.

On aerial photographs variations in moorland vegetation are revealed primarily as different shades or tone of black to white[2] dependent upon the degree of absorption or reflection of light

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1 Fenton, E.W. (1950)

2 differences of texture can sometimes be discerned as between contrasting plant communities if the prints are particularly clear. Shadows are most used in identifying types of trees (coniferous v deciduous) or man made objects such as dykes, drainage ditches, cultivation furrows, etc.

by a particular type of vegetation - and this of course may vary according to the time of year, the height of plant growth and the age of the plants when the particular photograph was taken. Hence the appearance of a particular type of vegetation may reveal wide variations from one set of photographs to another according to the season, the time of day, visibility and general weather conditions prevailing at the time of the sortie. Also the scale of the photographs and the quality of printing may cause variations of uniformity within any one particular sortie.

The complete air coverage which existed for all three sample areas was thoroughly examined prior to the final mapping of vegetation. In all cases the relevant photographs had been taken between April and June but while those for Newton Stewart and Peebles dated from 1946 those for Wanlockhead had been taken in 1950. Also the photographs varied considerably in quality and clarity within and as well as from one area to another. Generally of a scale of approximately 1:10,560, this was rarely constantly maintained varying either above or below this amount. Throughout the three areas the types of vegetation most easily identifiable are:-

1. Heather: often black to dark grey with the characteristic pattern of rectangular patches of varying shades of black → light grey resulting from rotational burning (F. 66 (35) : F. 73 (65)): rarely any indication however, unless hagging is conspicuous, whether it is on 'hard' or 'deep' land (F. 75(69) : F. 76(70)).

2. Grass: varies very considerably from white to all shades of grey dependent on length, composition etc.: Agrostis-Fescue hill-pastures usually evenly light grey (F. 67(36)): Nardus-dominated grassland, when well developed, usually shows up as often brilliant white with sharply defined boundaries (F. 75(68)(69)): Molinia, particularly if long, pure and well tufted may also be white (F. 57 (1)(3)(4)) but, even then, on other photographs it may be of a grey tone - only slightly darker than that of the Agrostis-Fescue grasslands (F. 68 (37)): the boundary between Molinia and Agrostis-Fescue is frequently sharp especially when associated with, as it often is, a well-marked and abrupt change of gradient (F. 68 (37) and F. 57 (3)).

Areas where the vegetation cover has been broken and mineral soil exposed are usually consistently revealed on photographs as a white shade but can generally be distinguished by the characteristic form of either gullies, sheep scars or rabbit burrows (F. 66 (35) F. 67 (36).

Also it should be noted that aerial photographs are often of considerable assistance in assessing the proportions of a mixture of especially heather and grass (F. 73 (65)) in a particular area and hence how best it should be classified.

3. Wet Moorland: areas of any depth of peat are usually of a dark shade, dark grey to black which delimits them clearly from dry or intermediate

associations (F. 77 (72)). Identification is further assisted by a regular and geometrical pattern of drainage ditches (F. 78 (73)) or hags, the latter showing up clearly as a pattern of white reticulate or dendritic lines, veining especially thick peat caps (F. 75 (68) F.76 (70)). Vividness of lines is generally dependent upon depth and degree of dissection.

4. Bracken: usually light grey and difficult to distinguish from Fescue-Agrostis grass: but where high and dense can often be identified by a characteristic 'curley' texture (F. 77 (72) F. 78 (73)).

Aerial photographs are further useful in their revelation of the extent of such features as artificial drainage, heather burning, peat cutting, natural erosion and gullying, abandoned cultivations (F. 59 (7)), in-bye and improved land (F. 74 (66)) and particular landforms, all factors of considerable importance in the attempted interpretation of the status of different types of moorland vegetation.

Aerial photographs were used for all these areas, in the course of the production of the final vegetation maps, to check and define the extent and limits of improved land and woodlands as compared with the earlier produced Ordnance Survey maps and also, where possible, to assess the extent of man's modification of the moorland vegetation and where possible to check the extent and limits of the vegetation communities deduced on the basis of field work. Undoubtedly however their greatest asset as far as the mapping of moorland vegetation is concerned is in their ability to provide a 'bird's eye' view of the whole of an area and hence to assist in the maintenance of a sense of proportion in assessing the relative importance of various facets of the landscape and also, and not least, in providing a salutory reminder of the often extreme diversity of the actual pattern presented by the vegetation on the ground.

Vegetation Maps: The final task preliminary to the actual construction of the vegetation maps was to decide in what manner the various associations could best be represented. There is little doubt that for the representation of associations over wide areas on medium scale maps there is much to be said in favour of colour (with or without the accompaniment of symbols or shading) as a means of providing the greatest degree of clarity - provided that the shades used are distinctive and clearly distinguishable one from the other. This is admirably illustrated by those primary survey maps on scales of 1:126,720 or 1:63,360 produced under the auspices of the British Vegetation Committee between 1900-1913. They are further to be recommended for the effort that was made to maintain a fairly standardised range of colours for particular and closely related associations on different maps. It is certainly more difficult to attain the same clarity and above all sufficiently well marked contrasts in the production of black and white vegetation maps; also the selection of suitable symbols that can be readily recognised and differentiated needs some care. However the difficulty and expense of publishing coloured maps is one of the principal deterrents to the use of an otherwise admirable technique and certainly where reproduction has eventually to be followed by reduction, as necessitated in this instance, there is no alternative to the use of black and white.

In order to facilitate a visual comparison of the vegetation of the Newton Stewart, Wanlockhead and Peebles areas, it was necessary to construct a standardised set of symbols and it was therefore decided to adopt with some modifications Professor Salisbury's very excellent scheme for the representation of the vegetation of the British Isles in black and white[1] (See diagram F.2.). This allows for a clear and basic distinction to be made between wet and dry moorland vegetation, improved agricultural land, woodlands and Forestry Commission plantations. The actual symbols used within this framework to represent the various associations of the moorland vegetation were chosen with a view to providing as clear a distinction as possible between individual communities while at the same time allowing for the necessity of overlaps and the interpenetration of two associations, to suggesting by the shading effects produced by the density of symbols the relative colour contrasts visible on the ground and to illustrating clearly and concisely the principal distributional

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[1] Salisbury, E.J. (1920)

pattern of the various associations. Unfortunately the effect and success of a particular combination of symbols cannot be fully estimated until the map is complete.

With the aid of the field map, field notes and aerial photographs the various associations were finally plotted on a base map of scale 1:25,000. This particular scale was chosen largely because it allowed a greater ease of construction of the map and of the various symbols than would have been possible on a scale of 1:63360, and although the actual amount of detail to be shown did not necessarily warrant this slightly larger scale, it did permit the representation of certain features, important to the understanding of the nature and status of the vegetation, that would have been difficult to illustrate accurately or clearly on a smaller scale. No boundary lines have been drawn between the different associations but despite this precaution the junction where one association begins and another ends is sometimes more abrupt and clear-cut than is the case in nature. It must however be remembered that the limits of the associations as indicated on the vegetation maps are often arbitary and generalised and only in certain and indeed rather exceptional instances can they be drawn with complete confidence and accuracy.

Beyond the limits of the unimproved moorland vegetation of the rough hill grazings no detailed mapping was attempted and emphasis was directed mainly towards indicating clearly the extent and altidudinal limits of improved agricultural land of any kind. This could be achieved most successfully on a black and white map by leaving all improved land blank and free from symbols. On the basis of the Smiths' classification of "Cultivation with Wheat" and of "Cultivation without Wheat - with Oats only"[1], all the improved land in each of the three areas could be placed within the latter group. Attempts to differentiate between arable land, temporary grassland and permanent pasture would not have served any particular or useful purpose as far as these surveys were concerned. It would probably have led, consequent upon the necessity for an even greater number of symbols to unnecessary confusion. Also, since the rotational pattern of the cultivated fields is constantly changing, such a classification would have been of but a short-lived value. The extent of woodlands, and the differentiation as between coniferous and deciduous trees, are based on those indicated by the O. S. 1:63360 maps (6th ed.), amended from aerial photographs. Woodland, however, managed directly or planted by the Forestry Commission has been represented separately, and its extent is that at the time of each survey; it will therefore be appreciated that the rate of planting, especially in the Newton Stewart area, has already rendered the limits of such plantations indicated on the vegetation maps somewhat out of date.

Finally, while bracken (Pteridium aquilinum) is prevalent and widespread in all three areas forming a distinct plant

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[1] Smith, R. (1900)

association and frequently indeed a pure consociation in which it may be dominant to the exclusion of all other species (although it is more frequently accompanied by a grassy ground layer), it was (for various reasons) decided <u>not</u> to represent it as a separate and distinct association on the vegetation maps. With its primary requirements of a <u>well-drained</u> soil of reasonable depth and a sheltered site it must be considered as a probably relatively recent invader of much of the lower and more favourable parts of the dry moorland communities in these upland regions. As Anderson points out, "bracken is not recommended as a suitable indicator of site ...... Bracken grows on a wide range of fertility-classes and seems to indicate one thing only and that is a depth of porous well aerated soil of at least six inches"[1]. Within a zone, limited only by certain suitable soil conditions and extreme exposure to wind, bracken, in all three areas is at times dominant, forming a dense closed community, at others it occurs scattered diffusely throughout dry heather and/or dry grass associations, while in places it may be completely absent. To indicate by a separate symbol exact areas where bracken is completely dominant would indeed be very useful and enlightening in many respects; however, the often irregular incidence and relatively small extent of such individual areas made their detailed mapping in the field, as it was soon discovered, too expensive of time. Had such a course been followed, however, any attempt to plot exact bracken dominated

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1 Anderson, M.L. (1950) pp. 35-36.

areas on a medium scale map would not only have been difficult but would have led to considerable and unnecessary confusion. To merely delegate by means of a particular and distinct symbol the whole of the probable zone in which bracken was prevalent to this one association would have been a drastic and misleading overgeneralisation. In view of these considerations, it was decided eventually to follow Stapledon's suggestion[1] and only to indicate the '<u>bracken zone</u>' by representing the approximate and, in general, the average maximum upper limit of growth of this plant by a continuous line on each of the three vegetation maps. Sensitive as the bracken fern appears to be to harsh climate conditions and particularly to the excessive exposure to wind consequent upon higher elevations, it was considered that a comparison of its altitudinal extent as between the three areas might reveal the effects of different climate conditions and particularly of exposure between the south west and north east of the Southern Uplands. There is however little doubt that if time had permitted, a calculation of the percentage area completely dominated by bracken within each respective zone would have provided an extremely useful complementary record.

In conclusion, it might be said that in their fundamentally 'exploratory' nature the studies which have been undertaken and whose results are presented in the following sections, partake of the character of reconnaissance surveys; on the other hand, in their concurrent attempts to classify, define and delimit

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1 Stapledon, R.G. (1937)p. 21.

certain types of vegetation and their habitats they must be considered as primary surveys. Although the field work was conducted with a view, for various reasons, to the final recording of results on a medium scale map the construction of vegetation maps was always regarded as incidental or complementary to, rather than as the principal aim and ultimate objective of, the field studies. The maps were finally constructed for the purpose of providing as clear and as concise a synthesis and resumé of the conclusions reached in the course of field work as to the recognition of various plant communities, their regional distribution and their possible relations to particular habitats. However, throughout all three an effort has been made to make as natural a grouping of the vegetation as possible and to represent, as far as the scale of mapping would allow, the vegetation as it occurs on the ground. It is felt that the considerable amount of time that had to be devoted to the resolution of the various problems concerned with the mapping of vegetation, as well as to the actual construction of the maps, has been fully justified.

SECTION II

THE NEWTON STEWART AREA

CHAPTER III

The Geographical Introduction to the Newton Stewart Area.

The Newton Stewart area, covering some hundred and twenty square miles of 'hill-grazings', lies directly north east of the town of Newton Stewart. The original sample area chosen (see F. 3) was that bounded by the River Cree to the west, by the Bargaly Glen-Palnure Burn to the south east, and by the line of Glen Trool-Loch Dee-Clatteringshaws Loch to the north and north east. As such it provided a fairly compact and well defined area of hill ground on the south western limits of the Southern Uplands which, east of the River Cree, rises abruptly above the low moors and Machars of Wigtownshire and which, in consequence, is fully exposed to the west and south west. Further in comparison to the more remote and unpopulated Merrick-Kells ranges to the north, it is an area relatively easily accessible from the whole of its periphery.

Landform and Geology. This 'hassock of land' whose altitude ranges from less than 100' in the west and south west to over 2000' in the north centre (Lamachan 2350')[1] is underlain by Ordovician and Silurian sediments (see F. 4) so highly and complexly folded that their component strata, which strike in a north-east to south-west direction, are either vertical or very steeply inclined over much of the area. To the north, highly folded and compressed Ordovician greywackes, shales and mudstones, intercalated with occasional beds of coarse conglomerate are

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1 Ref. /435770

interrupted by lenticular inliers of, again strongly folded, cherts, mudstones, and black shale, exposed in the cores of denuded anticlines. The southern belt of Silurian greywackes[1] and shales is of a fundamentally similar structure, if somewhat more uniform in composition. However, over the whole area the predominant bed rock is the close grained gritstone - greywacke- considerably fractured and shattered where exposed in outcrop and quarry. While the prevalence of this rock type is certainly inclined to obscure the complex geological structure, weathering and erosion of the vertical and steeply dipping strata has contributed to the most striking physical characteristic of the area - a pronounced ridging and furrowing which grains and scours the surface of the land from north-east to south-west.

This graining is most pronounced below 1250'-1000' over a belt of low moors, which varying in width from $1\frac{1}{4}$-4 miles, fringes the area to the north, north west and south east. Westwards from approximately 250'-500' along the flat holm lands of the Lower Minnoch-Trool rivers and northwards, from the same height above the steeper banks of the Middle Cree and the Bargaly Glen, these low moors rise in altitude to between 1000'-1250'. Their surface is, however, particularly to the north west of the Bargaly Glen, so diversified and broken by steep-sided knowes and ridges as to obscure on the ground the more gradual rise in

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1 Greywacke:- grey composite gritty rocks varying in texture from fine grained rock to coarse quartzose grit and comprising grains of quartz, mica, felspar etc., or rock fragments set in a fine argillaceous matrix.

altitude.

At approximately 1000'-1250', this outer belt of low moors, terminated very abruptly in places by a marked break of slope, gives way to a central knot of hills which rise steeply above it to summits of between 1500'-2000', and whose slopes drop steeply on their northern flanks to the valleys of Loch Trool, Loch Dee and the River Dee. The graining of the low moors is maintained, though to a lesser degree, over these higher hills up to heights of 1750'-1900', so that the steep, generally convex slopes, and the plateau-like remnants which form their summits have often a ribbed and uneven surface. It is only on the highest summits and slopes of the Larg (2216')[1] - Lamachan (2356')[2]- Cambrick[3] line of hills that any smoothness of surface remains to remind one of the Eastern Southern Uplands. The projected profiles (see F. 5 A and B) drawn from east to west across the area indicate in a generalised manner the uneven surface of the low moors below 1000' which fringe the north central hill group. The latter, especially in the west, rises by a marked break of gradient above the low moors, while in the east falls more abruptly to the River Dee.

This irregular group of hills forming part of the somewhat ill-defined watershed between the Rivers Dee and Cree (see F. 6) is penetrated and dissected by the long, narrow, well defined valleys of the Trool-Glenhead Burn, the Penkiln and Pulnee Burns,

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[1] Map Reference /425756

[2] " " /435770

[3] " " /432777

and the Bargaly Glen, which drain south-westwards towards the Cree, deep and narrow and often trough-like in their upper reaches, widening and broadening across the low moors. The shorter but still well defined deep valleys of the White Laggan, Craigencaille Lane and the Darnaw Burn drain north and north-east to the River Dee. In addition numerous small youthful burns, rising at the base of the higher hills (at the inner margin of the low moors) or on their steep slopes flow in irregular ungraded courses across the uneven surface of the low moors, north-west and south-westwards, towards the Minnoch and Cree rivers and south-east towards the Bargaly Glen. Their courses, diversified by rocky linns and miniature defiles across upstanding ridges and sluggish meanders over the intervening flats, reflect the nature of the terrain across which they flow.

The survey was later extended on to the two granitic masses of the Loch Doon complex and Cairnsmore of Fleet (2392')[1] which lie north and south respectively of the area originally selected, in order to determine whether the different rock type revealed any significant change in the vegetation. Time allowed only very small sample surveys of each to be incorporated (see F.3 and F.4). In the north, a southern projection of the Loch Doon granite presents a low (1000'-1250') uneven, boulder-strewn and lake-dotted plateau, bounded by steep slopes. In the south, the intensely grained low moorlands are continued south-east of the Bargaly Glen across highly folded and in some instances

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1 Map Reference /502671

metamorphosed Silurian shales and greywackes; above them the massive granite of Cairnsmore of Fleet rises from about 1000' with steep, and, generally smooth, though boulder strewn, slopes which culminate in a broad plateau summit of between 2000'-2500'.

The broken and scoured nature of both upland and low moor, with over-steepened ice-plucked and ice-scraped surfaces on granite and greywacke alike, the incipient corries, scars and screes which break the continuity of slope on the higher hills, the narrow trough-like valleys of Glen Trool, Glenhead, and the Upper Penkiln Burn and the Bargaly Glen all tell of considerable glacial erosion. Charlesworth[1] considers (see F. 7) that during its maximum extension the Pleistocene ice moved north-east to south-west across this region; at a later stage, valley glaciers, originating in the gathering grounds of the Loch Doon basin further north and escaping southwards, broke through and, no doubt, breaching the main watershed, moved westwards along the Trool, southwards from Loch Dee into the Penkiln-Pulnee Burns, and south-westwards from the River Dee along the Bargaly Glen. It is more than probable that such a movement of ice accentuated and intensified the Caledonian grain, particularly of the low moors though, in some instances, it scoured across it, imposing in places a less well-defined north-south ridging. Whatever the cause, the result is what best can be described as a mammilated surface, on which a certain measure of order has been imposed by the Caledonian strike of the Lower Palaezoic rocks.

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1 Charlesworth, J. K. (1926a.)

It is only in irregular and discontinuous patches that superficial deposits (see F. 8) attain any depth or extent. Glacial till spreads across the floors and lower slopes, to a height rarely exceeding 1000', of the Upper Dee and Trool Valleys and their major tributaries. Another more extensive spread laps around the western base of the central hills from which tongues of glacial material penetrate up the intervening valleys. While usually limited to about 1250', it may exceed this altitude, to as much as 1500', at the heads of some of the deeper valleys. In many cases the till, as mapped by the Geological Survey, is masked by a layer of peat of variable thickness and consistency. Where, however, it has been exposed by river erosion indications of the difference between what is mapped as morainic material and as boulder clay are revealed. The former consists usually of a coarse heterogeneous debris containing a high percentage of boulders, often large, many of them granitic. The latter appears to be composed of a sticky black to grey clayey matrix binding together a fine gritty to sandy material.

Other superficial deposits are represented by alluvium whose most continuous distribution is confined to the meander flats of the Lower Minnoch River, the wider valley floor of the Middle Cree and the haugh land on the flat bottom of the deeper Bargaly Glen. In the extreme south-west of the area fragmentry terraces of a sandy material border the Lower Cree and the Penkiln Burns and grade imperceptibly into the raised beaches of the Cree estuary. These lighter, finer deposits constitute, however, but a narrow fringe to the area under consideration - a hill area on which glacial erosion has left a distinct mark and over which spreads of morainic material do little to ameliorate the harsh and broken relief. It is a harshness of landscape which has little in common with the Eastern Southern Uplands and which has all but obliterated the smoothness of contour and plateau summits. In aspect, if not in scale and altitude, the affinities of this area lie rather with the Western Highlands of Scotland.

Climate. If the relief and landform call to mind the Western Highlands of Scotland, the climate of the Newton Stewart is in no less degree western in character. Galloway enjoys, in common with most of Western Scotland, a generous and well distributed rainfall, a generally high atmospheric humidity, and relatively mild equable temperatures consequent upon its westerly and oceanic aspect - characteristics which are however modified within the restricted extent of the Newton Stewart area by its rapid range of altitude. The graphs of F. 9 summarise the principal climatic elements for the district as a whole, as given in the Meteorological Atlas of the British Isles[1]. The average annual rainfall (see F. 10) already heavy, and indeed excessive from an agricultural standpoint, of 40-45" along the Cree Valley increases rapidly east and north-eastwards to over 70" on Cairnsmore and the central

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1 Meteorological Office (1952)
Though it must be remembered that most of the elements, and in particular, temperatures, are represented by sea level values only.

group of hills - attaining an average of over 80" on the higher Merrick Range to the north. With the probable average annual average isohyet for 65" coinciding approximately and in the west of the area only, with the 1000' contour, at least half of the 'hill land' under discussion receives over 60", if not over 65", per annum. There are also indications that on the eastern lee side of the area, either above or below 1000', the average annual rainfall amount is slightly higher than on the western exposed side[1]. It is a rainfall well distributed throughout the year, the winter period from October to March with 55-60% of the annual total only slightly in excess of the summer amount from April to September with 40-45%. Within the former period no month has on an average less than approximately 4" of rain, and the mean monthly maximum, occuring generally in December, though at some stations in January, varies according to altitude, from 5"-8". The latter period is characterised by a more or less well defined "dry spell" from April to June, with monthly means usually less than 3", but which is, however, offset by a marked increase in July and/or August, when, in some instances, the mean monthly rainfall of these two months together does not fall much short of the mean monthly winter maximum. This usually well-marked secondary summer maximum is succeeded by a slight but nevertheless characteristic secondary minimum in September. Indeed June and September are the recognised dry months of the area not, however, always realised in view of the

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1 Gauld, W. A. (1922a) p. 30.

variable nature of the year-to-year rainfall. The high rainfall amount is further reflected in a relatively large number of rain days, an average of 225 (61%) for the area as a whole, with a maximum of 23 (74%) in December and a minimum of 13 (42%) in June.

The high rainfall consequent upon the unimpeded westerly exposure of this hill area is accompanied by a frequently low cloud base and a frequency and persistence of hill fog and mist[1], in both the summer and winter months and a relatively high atmospheric humidity.

Detailed data about humidity are not available and the general monthly and annual averages of relative humidity and saturation deficit express very inadequately the tangible humidity of the atmosphere of this area whose wet moorlands seldom dry out completely, even after a long period without rain. Further, the effectiveness of evaporation must be limited by the generally mild, and in particular relatively low summer, temperatures. The mean of the coldest month, January, for the district is given as $40^{\circ}F$ and does not drop below $38^{\circ}F$ for the few reliable stations situated on the periphery of the hill land (see F. 11); while mean temperatures for the warmest month rarely exceed $58^{\circ}F$. The mean maximum range is slightly higher, but not excessive, a mean minimum from 65°-$66^{\circ}F$ for the

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1 One of the reasons for the relatively large number of aeroplanes which have crashed on these hills.

warmest, to a mean minimum of 30°F-35°F for the coldest month. Mean monthly ranges similarly are relatively low, 9°F-10°F in the winter months and 17°F-18°F in the warmest. Reliable temperature records for stations situated below 500' indicate a period of between 7 to 8 months during which monthly means are consistently over 42°F, with monthly minima exceeding this value for 6 consecutive months, and with monthly maxima never falling below it.

These are all values however which must be considerably modified not only by the altitude of the area in question but by the minutiae of relief, exposure, aspect, and degree of slope. While it is difficult, in view of the total absence of temperature records over 200', to attempt any assessment of the extent to which relief and the finer details of landform influence climate, and in particular temperature, the reduction of low level means to give values for selected altitudes can provide some approximation of the changes of temperature imposed by increasing altitude. Such an approximation indicates that in the Newton Stewart area at 2000', while the mean temperatures of the warmest month may be in the region of 50°F-51°F (mean maximum 57°F-60°F) those of the coldest month would appear to fluctuate around freezing point 31°F-30°F (mean minimum 23°F-28°F). This represents an approximate reduction of the period during which mean monthly temperatures exceed 42°F by about 2 - 2½ months.

Yet again, detailed data regarding the frequency and occurrence of either air or ground frost are lacking. Only for the district as a whole are average figures available, indicating an average annual frequency of 50-100 days with minimum temperatures of less than 32°F and a frost-free period whose average limiting dates lie between 1st and 15th October for the last screen frost and between 1st and 15th May for the first. These, however, must be somewhat over generalised and unreal in view not only of the altitude and topography but also of the excessively ridged and uneven nature of the surface. This ridging, so often running across the slope, must accentuate the risk of both early and late local frosts in the intervening flats[1]. The liability to frost in such depressions and hollows may be further increased by the fact that they are commonly occupied by wet peat from whose surface the rapid evaporation of water must increase the cooling effect when drier air from adjacent mineral soil (i.e. on the surrounding knowes) moves across it[2].

The generally mild winters are reflected in the relative paucity of snow-fall and snow-lie. With an average of from 10-30 mornings with snow lying, the amount is rarely excessive. Even between December and March, the period of maximum snowfall, the number of mornings with snowfall does not exceed 5 for the district. In the latter figure no account of altitude is taken but the opinion of local shepherds would seem to suggest that, apart from the exceptional years, neither the amount nor duration

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1 Kirroughtree Forest Nursery lies in a conspicuous hollow at only 200'. The Forester here told the writer that ground frost occured even in August on occasions.

2 Fraser, G.K. (1933) p.12

of snow cover at higher altitudes is so great nor so long as further east.

There is even less quantitative information about the final but by no means least important element - wind. It is locally acknowledged that the prevalent west and north-west winds are strong and persistent, but south winds are frequent. Although the area lies some 20-30 miles inland from either the west or south coast of Wigtownshire, the low relief (seldom exceeding 500') of the Machars and Rhinns of Galloway leaves the westerly-facing hill slopes completely exposed. In addition, the north-east - south-westerly alignment of the three principal tributaries of the River Cree, Glen Trool, the Penkiln and Palnure Burns, must allow considerable penetration of these westerly influences, particularly in the case of Glen Trool and the Bargaly Glen where the pronounced valley lines are continued eastwards, over very low watersheds, by rivers draining towards the River Dee. A considerably high wind force has been experienced personally on many occasions in the Bargaly Glen whose alignment, depth and constriction would appear to canalise westerly and south-westerly winds to a marked degree. Indeed, to the westerly exposure and oceanic position of this hill area must be attributed the general climatic characteristics of abundant and well distributed rainfall, high atmospheric humidity, low summer and mild winter temperatures and a relatively small range of annual and monthly temperatures.

Land Utilisation. Bearing in mind the physical characteristics of the Newton Stewart area it should occasion no surprise that although a considerable proportion of the land lies below 1000', a high percentage - at least 80% - of the surface carries unimproved moorland vegetation. The vegetation map (see F. 12) illustrates this at a glance. Arable or improved agricultural land of any kind is small, indeed rigidly within the area surveyed, negligible in amount and, restricted in extent largely to the western and southern margins of the area, can be broadly classed in three locality groups...

on 1) the flat, though discontinuous stretches of 'holm' or 'haugh' land, where, bordering the lower Minnoch and Middle Cree valleys, and along the flat bottom of the Bargaly Glen, river alluvium provides a fine sandy-loam soil. This in the main provides valuable in-bye land for those sheep farms fortunate enough to have such holms incorporated within their marches. Hay, oats, and turnips are grown providing winter feed especially for the black Galloway cattle which these more favourably placed farms run on the hill during the summer months. Unfortunately they are localities extremely susceptible to flooding when the rivers are in spate.

on 2) the sandy soils of the fluvio -glacial terraces of the lower Cree and lower Penkiln Burns, and on their continuation into the raised reaches of the Cree estuary, where the hill sheep farming is replaced by the ubiquitous dairy farming of Wigtownshire.

on 3) the low spur directly west of Minnigaff (and directly north of Kiroughtree Forest) where the only large patches of improved land are found on the more favourable localities of the low moors. Here improved land cuts across a variety of subsoils ranging from boulder clay (till), sandy terrace deposits, to friable greywacke, and accounts for 25%-50% of the acreage of a few small marginal land farms.

Together these three areas account for the more pronounced zone of improved land to the west and south of the rough moorlands, a zone which widens and increases in extent southwards to the Cree estuary. The altitudinal limit of cultivation and improvement is low, in general between 250'-300', coinciding with the outer limit of the 'low moors' and only occasionally does it extend on to them. Even then, its maximum limit is rarely over 450'. Certainly isolated patches of in-bye land, of some 2 to 3 acres, produce hay (usually a mixture of Anthoxanthum odoratum and Holcus lanatus) for the more isolated farms and shepherds' houses. Located usually on better drained slopes they often extend up to 750'-850', particularly in the west of the area; indeed traces of lazy beds, long since abandoned, abound and are still visible at 900' in the Upper Penkiln Valley. In general however, within the Newton Stewart area the physical character of the low moors is one of the principal factors restricting the altitudinal limit of cultivation to an average height of 250'-300'. The intensity of its ridging with the rapid alternation of knowes and flats, a large proportion of steep slopes and bare ice-scraped rock surfaces, thin mineral soils, the development of boggy conditions and thick acid peat wherever natural drainage is poor, these, combined with an average annual rainfall of 50"-60" per year, must defeat even the most energetic of Scottish farmers.

With the exception of the few marginal land and dairy farms around its periphery, the Newton Stewart hill area is at present utilised primarily for the breeding of black face sheep. A block of some nine large hill sheep farms, ranging in size from 2,500 acres -over 5,000 acres, dominate the area. With their marches radiating from the central knot of hills, all, with but one exception, cut across and incorporate within their boundaries a sample of the principle land forms, from high hill across low moor to glaciated valley. The percentage of hill land under 1000' is in all cases high; in the majority it represents over 40%-50% of the total surface while, in contrast, the proportion of land over 1500' is relatively small, usually less than 15%. Valley floors are restricted in extent, the larger and wider valleys confined to the margins of the area. The 'Core' or 'Eye' of most of these hill farms is centred on the low moors. Stocking, as far as can be ascertained, varies from 5 acres to 2/3 acres per ewe, the increase in density becoming more apparent in those farms which, situated to the west of the area, possess the highest proportion of low moor and, in addition, whose acreage of in-bye land is relatively higher than elsewhere. These more 'favoured' farms have since the introduction of the subsidy on hill cattle been running in summer herds of black Galloway cattle on their hill ground.

The wide variety of different types of vegetation and the less severe climatic conditions particularly in the lambing period than experienced farther east are undoubted assets to the sheep farmer in Galloway but, on the other hand, many of the difficulties - problems inherent to sheep farming everywhere in Scotland to-day - are here intensified by natural conditions. The wild, rough, broken nature of the land with the prevalence of boggy and wet conditions especially in low ground make herding extremely arduous. Hill ponies would provide an obvious solution, as in the Highlands, but only one shepherd in the area uses intermittently such a means of transport. The farm steadings and shepherd's houses situated around the margin of the area are rarely more than five miles from a metal surfaced road but access to the interior of the hill area is difficult and practically all the shepherds houses which formerly served this area have been empty for twenty years or more and the rough tracks which once reached them are now virtually obliterated. Shepherds and farmers are unanimous, especially towards the west of the area, on the subject of the large proportion of land which must be regarded of as negligible value agriculturally by reason of bare rock surface, neglected drainage, and widespread bracken. Indeed one farmer went as far as to say that of his 5,000 acres, a 1,000 acres, for one reason or another, could be regarded as useless. In-bye land of any value is small and the possibilities of extending it in view of both a shortage of labour and adverse physical conditions are not great. Finally there is good reason to suspect that the mildness and wetness of the climate increases the tendency towards diseased land - particularly tick-borne infections and maggots.

During the depression in sheep farming between the two wars this area suffered badly - although it would be difficult to say to what extent compared with other parts of Southern Scotland - resulting in some cases in overstocking and, in others, in land standing empty for as long as ten years. It was during this period that the Forestry Commission acquired possession of practically all of this area which, extending northwards to the Merrick-Kells area, has now been designated as the Glen Trool Natural Forest Park. The compact block of coniferous plantings in the south, the Kirroughtree Forest, was first established in 1930-32. Since 1945 the rate of planting has become more rapid and, year by year, the gap between the Kirroughtree Forest, Glen Trool Forest to the north and Cairn Edward Forest to the east decreases. It is worth noting that at present the upper limit of the land designated as plantable is in the region of 1250', the high degree of exposure and lack of shelter on the higher, steeper ground being considered as one of the most important limiting factors. In addition, the amount of unplantable land is high even on low ground where deep peat often in enclosed pockets defies attempts at drainage.

The dominance of black face sheep breeding is giving way slowly, but inevitably, to forestry although how complete will be the replacement is still uncertain. Plans to preserve broad rides linking the original steadings with the unplanted hill tops have been suggested. However, while the land utilisation pattern is changing fairly rapidly at the present time, the quality and success of the older sheep farming and the more recent forestry developments are closely linked with and are indeed, to a large extent, dependent upon the present nature and condition of the moorland vegetation.

CHAPTER IV

Vegetation of the Newton Stewart Area - Wet Moorland.

The heavily glaciated nature of the Newton Stewart area with its intensely roughened and broken topography results in a vegetation cover so diversified as to virtually defy a reasonable classification on a purely botanical basis, which could at the same time be clearly represented on a map whose scale did not exceed 1:25,000. The result has been that, in an effort to analyse the main characteristics of this cover, it has been necessary on the vegetation map (see F. 12) to classify, as far as possible, the vegetation of this area into a number of associations each of which as well as being recognisable by a distinctive colour, imparted by the presence and combination of certain dominant moorland plants, can generally be related to a particular physical habitat provided by a distinct type of landform. Indeed here, to a greater extent than in the other two areas in the east, a particular association may owe its definition as much to the nature of the land surface on which it is found as to its particular botanical composition.

Of the two groups - wet and dry moorland - into which the associations fall, the former is by far the most widespread. It includes both blanket and topogenous bog, but the two types interpenetrate to such an extent that it would be difficult to attempt to differentiate them clearly. The peat underlying the wet moorland varies considerably in depth (from less than 2' to over 15'), in acidity, and in moisture content, and supports a vegetation cover which may be completely dominated by one species or may be composed of a mixture of two or more co-dominants together with many other associated species.

On the basis purely and simply of dominant species the wet moorland, in spite of the complicated and extremely diverse appearance that it presents to a preliminary and superficial view, resolves itself into three principal associations, each characterised by a distinctive colour and whose distribution can very broadly be correlated with altitude.

They are:-

1.	Molinia 'flow'	(Molinia caerulea)	dark green	under 1000'
2.	Mixed Moor	Calluna vulgaris Scirpus caespitosus Molinia caerulea	purple	under 1500-1750'
3.	Scirpus Moor	(Scirpus caespitosus)	reddish brown	usually over 1500'

Molinia 'flow' [1]

In its finest and purest form the Molinia 'flow' association is dominated, often to the exclusion of all other species, by large coarse tussocks (attaining 1'-2' in height and 1' in diameter) of Molinia caerulea growing on deep wet, black to brownish peat of considerable depth and of a liquid mud-like consistency over which it is, at times, practically impossible

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1 McKerlie, P.H. (1891) p.137 - suggests that the word 'flow' commonly used in Galloway to denote a marsh or boggy moorland is from the Norse floī meaning a marshy moor. It is used in the above context because the word is considered singularly descriptive in many ways of much of this particular association.

to walk. Under such conditions its only associates may be Juncus articulatus in wide compact patches, and Myrica gale, again in local patches and often towards the outer margins of the Molinia association. These two species often form local 'societies' which interrupt the continuity of the Molinia and are not necessarily co-dominants. The distribution of the Molinia flow association in the Newton Stewart area is characterised by three basic facts which are clearly illustrated on the vegetation map (see F. 12). It occupies a marginal, or rather peripheral position in relation to the area as a whole; it is confined to low altitudes, generally below a 1000'; and, perhaps of most significance, it occurs mainly along the floors of some of the principal river valleys - particularly those to the north and north-east of the area, such as the Glenhead Burn, the River Dee and its right bank tributaries, and the Penkiln and Pulnee Burns (see F. 15/16;2(1)).

All these valleys exhibit to a greater or lesser degree, characteristics of form resulting from glacial erosion. Their cross sections (see F. 14) reveal the typical 'U' shaped valleys, deep, narrow, and with restricted floors towards their sources, gradually becoming wider and more open downstream with over steepened, at times almost concave, slopes falling abruptly to generally flat-bottomed floors. The latter, together with the lower bounding slopes are plastered with irregular spreads of boulder clay (till) and/or coarse morainic detritus. The longitudinal profiles reveal flat, smooth, maturely-graded reaches across which the river meanders sluggishly, alternating with breaks in gradient marked by rapids, rocky linns or even pronounced falls. This 'stepped' profile, so characteristic of glaciated valleys is not so striking along the more evenly graded courses of the larger rivers - such as the Dee (see F. 14 No. 1) and the Minnoch (see F. 14) - as along those of the shorter tributary valleys, particularly of the Buchan (see F. 14 No. 13), Penkiln (see F. 14 No. 7) and Pulnee Burns (see F. 14 No. 7a) which, in addition, hang above the main rivers.

The particular and specialised physical habitat provided by the form of these glaciated valleys or "lanes"[1] (see F. 57 Photo. (1)) with which the Molinia flow is so strikingly associated must have a considerable influence, be it direct or indirect, on the development and character of the vegetation. In view of the high annual rainfall of the surrounding hill land, and the relatively impermeable nature of the bed rock, there must be a considerable and rapid movement of water down the over-steepened slopes of these valley sides towards the rivers and their flats. The flow however will be subjected to a check in velocity and retardation of movement by the, often abrupt, decrease in gradient at the base of the slopes and no doubt, where it occurs, by the presence of the glacial debris, and, considering the generally low gradient of the rivers and burns crossing the

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1 "lanes" - local name normally given to wide, flat-floored valleys with sluggish meandering rivers. e.g. Cooran Lane, Craigeneaille Lane etc.

valley flats, the development of a waterlogged, but nevertheless continually flushed, area is not surprising. Along the narrower of these glaciated valleys, where the floors are restricted in width, or indeed along the outer margins of the wider floors, there, where the ground slopes just sufficiently to allow the movement and aeration of the water supply, but apparently not sufficiently to inhibit the development and accumulation of peat, the association dominated by strongly tufted Molinia attains its optimum development. Under such conditions it forms a very clearly-defined belt of dark green vegetation along the valley floors (see F. 57 Photos (1), (2a and 2b), (3)) between the river and the steep slope of the valley side; where the change in gradient is most marked a definite, and usually abrupt, boundary between the Molinia flow and the adjacent association results. However these optimum conditions do not persist over the whole of this particular habitat and it cannot be too strongly stressed that the composition of the Molinia flow does not maintain, what must be considered its optimum uniformity, consistently throughout the area classified as such on the vegetation map. Indeed, it exhibits considerable variations many of which can be related, to a certain extent, to variations in the form of the glaciated valleys themselves. Where, on the one hand, as around Loch Dee and northwards along the Cooran Lane, the valley flats are very wide there is a gradation, consequent upon the decrease of slope and increasing stagnation of water, into what appears from a distance to be 'raised bog'[1] of a more mixed character specifically and composed of deeper and more consolidated peat (see F. 58 Photo (4)). The content of these patches of deeper and higher peat, often isolated by the slight incision of the rivers was not investigated since at the time of the survey, the rainfall had been such that the writer was advised against going too far into and among these bogs without the assistance of a guide familiar with the ground.

On the other hand, where the valleys are wider, more open, and where their bounding slopes are less steep and less clearly defined, the pure Molinia assumes a more mixed character. While strongly tufted Molinia caerulea is still dominant with Myrica gale co-dominant, there is a higher percentage of associated species. Sphagnum (spp.) is frequent and often widespread over the ground layer; Erica tetralix is abundant; Narthecium ossifragum is frequent and very characteristic; while Scirpus caespitosus and Calluna vulgaris are commonly met with as well as sparse Eriophorum vaginatum. The underlying peat[2] may reach considerable depths (2'-15') and though still the characteristically

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1 Tansley, A.G. (1949a) p. 675 discusses the relationship between 'valley' and 'raised bog'. The latter term appears equivalent to that of 'HIGH MOOR' used by G.K. Fraser (1933) pp 7-11.

2 It is interesting to note that frequently it contains a distinct layer of birch twigs and branches at a depth of 1'-3' below the surface. It has also been observed at this depth in drained peat areas in the Loch Doon region (without this survey) and may perhaps be correlated with Lewis' birch layer, although it does not occur at so great a depth as in his sections. See F. J. Lewis (1905-6) pp. 702-703.

amorphous, very wet, black peat associated with Molinia, it is more compact, and not so liquid as that associated with the pure tufted Molinia.

On a purely botanical basis therefore, it is obvious that the Molinia flow association distinguished on the vegetation map (see F. 12) is in fact capable of further sub-division. For instance three of Anderson's plant communities or locality units[1] - 'Molinia', 'Myrica' and perhaps 'Sphagnum' - or 'Calluna-Moor' occur within it. Neither the scale of this map however, nor indeed the scope of this particular survey allows or justifies such a sub-division. The variations noted must be here regarded as "facies" of the Molinia flow, whose classification is based on two main criteria. First, it is characterised by the dominance of strongly tufted Molinia caerulea, usually accompanied by Myrica gale. Second, that it occurs most frequently and attains its optimum development, within that particular physical habitat provided by the glaciated valleys of this sample area. In some instances the limits of the association indicated on the map correspond to a clearly marked boundary line on the ground while, in others, they are arbitrary zones of gradual transition from this association to another. Under these latter circumstances the limits of Myrica gale which commonly occurs towards the edges of the pure Molinia flow have been used to define its boundary. Myrica is rarely found above 1000' and in this area reaches its altitudinal limit between 750'-850'.

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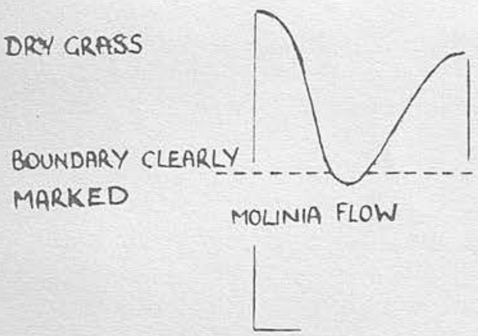
[1] Anderson, M.L., (1950) Chap. VI pp. 38,40,41.

DIAGRAM 1.

GENERAL DIAGRAMMATIC SUMMARY OF "FACIES", AND THEIR RELATION TO HABITAT, FOUND WITHIN THE MOLINIA - FLOW ASSOCIATION

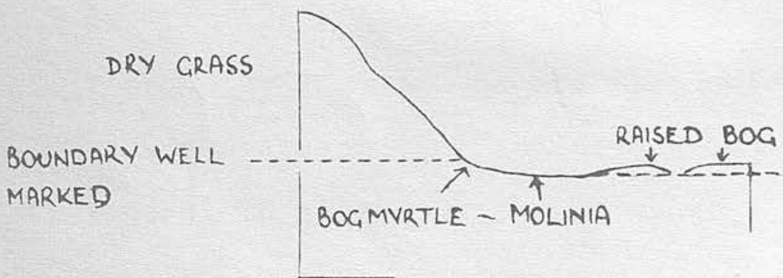
1.

MOLINIA FLOW, RESTRICTED IN EXTENT, ALONG VALLEY FLOOR.



2.

MOLINIA - BOG MYRTLE MARGINAL TO RAISED BOG
? STAGE STABILISED BY POSITION.



3.

MIXED MOLINIA IN LESS WELL DEFINED HABITAT
? SUB-SERAL STAGE TO CLIMAX DUE TO DRAINAGE

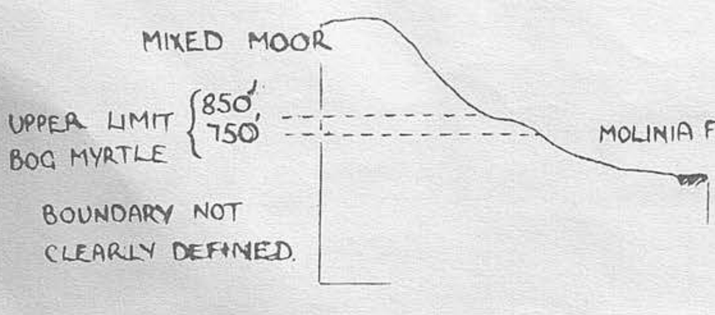


Diagram I (opposite) attempts to summarise the relationship in space, and the status, of these "facies" of the Molinia flow association.

Any attempt to assess how far this particular landform (see F.15/16: 2(1)) type affects, or can be directly correlated with the development of Molinia flow necessitates serious consideration of the habitat requirements and the status, as far as is known, of Molinia caerulea. A peat-forming plant with no well marked habitat preference and with a wide range of tolerance, it plays a prominent part both in the development of alkaline as well as of acidic peat.[1 2] The one essential for its development and maintenance as a dominant (a point on which all botanists are apparently agreed) would appear to be an abundant and constant supply of relatively fresh, aerated water. Jeffries[3] on the basis of work in the Huddersfield district of the Pennines, considers a slope of 1:18 as the minimum on which Molinia attains dominance, and notes that its tussock development is particularly marked where there is a free supply of fresh water. Similarly, MacVean[4] in his somewhat broader summary of the ecology of Molinia pastures observes that it is favoured, in the high rainfall areas of north-west Britain, by ground sloping just sufficiently to stimulate lateral movement of water and

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1 Gimmingham, G.H., (1944) gives pH values for Molinia 3 - alkaline.

2 Pearsall, W.H.,(1938) Part III p.298-315. gives pH values for Molinia 3.9 to over 4.4.

3 Jeffries, T.A., (1915)

4 MacVean,D.N. (1952)

consequent aeration.

There is also considerable agreement on the fact that on either acid or alkaline peat it represents a transitional or seral association rather than a climax, and, as such, is often found, particularly in the lowland moors of north and west Britain, situated marginally to the main peat areas.[1] Of the Scottish Molinia moors, Fraser says, "This type of moorland, although well marked and apparently very stable, may only be a stage in the development from mineral soil to Scirpus moor. Scirpus moor develops in the same region (the Borders) but at higher elevations where the rainfall is heavier and temperature lower. Molinia moor may be taken as the stable type, where summer temperatures are more effective in drying the soil and allowing an upward movement of water containing mineral matter from the underlying soil".[2] It is doubtful whether the necessary climatic conditions are to be found within this Molinia flow association.

Certainly there are indications in the Newton Stewart area that, despite its widespread occurrence, particularly over low ground, Molinia-dominated moorland does not represent the climax bog association but must rather be regarded as a stage in the succession or retrogression of the climax. Where slope conditions allow a rapid and plentiful flow of water, with

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1 Tansley, A.G., (1949a) pp. 713.

2 Fraser, G.K., (1933) p. 10.

percolation and temporary accumulation at its base, pure coarsely tufted Molinia on liquid peat may well represent a stage in the development of raised bog, to which, as has been indicated it does in fact occupy a marginal position on the ground. Yet its very position, between the river, or between the outer margin of the higher raised bog and the steep confining valley slopes, may here have imparted a certain stability and permanence to what might otherwise be a purely seral association. This may in fact be the case for certain localised parts of the Molinia flow particularly those which have not been interfered with by artificial drainage. Indeed in such a form, and under such conditions, it must be akin to Pearsall's Molinia-Myrica swamp[1] and Fraser's Molinia flush[2] two comparable developmental stages dependent upon a considerable accumulation of flushed water under physical conditions similar to those associated with Molinia flow in the Newton Stewart area.

Over the greater part of the association the problem cannot be resolved quite so simply, and yet another factor, the effect of man on the development of the vegetation, must needs be taken into consideration. Since these wide valleys provide the only relatively easy means of access into the hills, as well as the only really favourable sites for settlement, the exploitation of the low moors for cultivation, grazings, and peat fuel, though

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1 Pearsall, W.H., (1950) pp. 169-172.

2 Fraser, G.K., (1933) pp. 23-24.

now limited,[1] must have had a considerable effect on the vegetation. It is significant that practically the whole of the area now covered by Molinia flow has been, at one time or another, subjected to extensive draining by man; and to-day the surface is crossed by numerous drainage ditches, many choked and blocked or even partially obscured by vegetation but with their pattern clearly discerniable from a distance on the ground, or on aerial photographs. The writer is of the opinion that, while some of the Molinia-dominated moor may have developed, and be developing as a direct result of the particular physical character of the region, a larger percentage of it may be due to an artificial extension of those conditions which promote a more rapid and free flow of water by drainage; with periodic burning at the present time also contributing to the maintenance of Molinia as a dominant. If this is the case much, particularly of the more mixed Molinia flow, may represent a sub-seral stage to some other type of climax, of which the various species, Sphagnum spp., Scirpus caespitosus, Eriophorum vaginatum etc., occurring between the tussocks of Molinia, (may) represent relicts.

However, the frequent presence, already indicated, of an intercalated layer of birch wood in the underlying peat suggests that the original accumulation of this peat may probably have

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[1] Numerous abandoned shepherds' houses, traces of former settlement and evidences of old cultivations (mainly in the form of lazy-beds) along the valley sides are all indicative of a much greater population than now occupies these areas and certainly a more intensive use of the land.

been initiated by the development of a Molinia swamp or flush under conditions of high rainfall and the pronounced accumulation of water along the flat floors of the glaciated valleys and in the numerous depressions and hollows presented by the roughened glaciated ground surface. The pre-existing woodland of birch (probably with considerable alder and possibly oak) thus degenerated under this progressive accumulation; and, in view of the numerous associated bog species, it is perhaps reasonable to assume that a more advanced form of bog vegetation had developed before man appeared and artificial drainage was effected. Scattered clumps of alder wood, with willow, hazel and blackthorn still remain either along river banks, at the outer margins of the alluvial holm land, or on the margins of the Molinia flow, while on the steeper and better drained valley side slopes, particularly along the Trool valley, remnants of what may well be regarded as virtually natural oak-birch woods (with a grassy or mossy ground layer and with often a thick covering on tree trunks) still remain.

In the absence of a more detailed knowledge of the history of the vegetation and land use, there is little evidence to substantiate the application of this hypothesis to this particular area. A study of the results of recent drainage undertaken by the Forestry Commission complicates rather than clarifies the problem. In some cases certainly the drainage of deep peat areas dominated by either Sphagnum, Scirpus or a more mixed bog vegetation may eventually result in an association dominated by tufted Molinia caerulea, in yet other cases, by Calluna vulgaris.[1] The effect of drainage on peat vegetation is still, it would appear, difficult to predict and in view of the number of variable factors involved this is not surprising. An attempt to correlate varying degrees of peat acidity, depth, and moisture content, with the results of drainage in various contrasting physical habitats might be of considerable value.

In conclusion it must be borne in mind that the vegetation map only indicates areas of Molinia flow extensive enough to be represented clearly on this particular scale. The Molinia-Myrica gale association occurs frequently outside the limits of the area indicated on the map as Molinia flow but only in small patches. For various reasons which will be explained, the latter must be included in the most widespread of all associations mapped,

Mixed Wet Moorland. This association occupies practically 2/3rd's of the area of rough moorland vegetation shown on the vegetation map. Covering most of the lower moorlands, it forms, particularly in the west, south and east, a wide fringe which

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1 The writer is indebted to various officers of the Scottish Forestry Commission who gave unstintingly much of their time and knowledge of the area. They contributed valuable and first hand information on the problems and effects of modern peat drainage. They facilitated the inspection and examination of various drained and undrained areas in the Glen Trool National Forest Park. Full treatment of this particular problem is outside the scope and aim of this work. But it must be stressed as of considerable practical importance for the forester, since on the type of vegetation which develops after drainage may depend the success or failure of his young tree crop.

laps around the north central knot of higher hills. Although it most commonly occurs below a 1000', it attains, in the east of the area, altitudes of as much as 1500'.

As a vegetation association it can most easily be distinguished on the ground by its colour, assuming as it does the 'purple haze of the heather moor' which sets it in contrast with the light green of the "white" dry grass hills and with the darker green of the Molinia flow. The specific content of the association indicated on the vegetation map is far from constant and varies so drastically from one place to another that the broad classification used in this instance would not be justifiable on the basis of botanical content alone. On the other hand the botanical variations within it cover such small areas on the ground that it would be impossible to map each clearly and individually on a scale of less than 6" to a mile. In view of such practical difficulties, and on the basis that these variations are commonly found over a characteristic type of land surface it was deemed reasonable, and indeed necessary, to group them into one generalised association - an association, it must be stressed, whose classification depends <u>fundamentally</u> on landform. Any description and explanation of the mixed wet moor therefore demands, first, an analysis of its physical habitat.

The principal area covered by mixed wet moor (see F. 15(3a-d)) is one of low moorland which, flanking the main rivers, rises gradually from an altitude of about 250'-500', westwards from the holm land of the Cree and Minnock rivers and northwards from the Bargaly Glen, to about 1000-1250' where it gives way to the higher, steeper hills which rise above it. This belt of moorland varies in width from one to four miles. It presents two slightly different physical aspects - that to the west of the Pulnee and Penkiln rivers and that to the east. This is perhaps too precise a boundary and it would be more accurate to state that the area lying between the Penkiln-Pulnee Burns and the Cordorcan Burn further west is in the nature of a transition zone possessing some of the physical characteristics of the area to the west and some of those to the east of it.

To the west (see F. 15 (3a. and b.)) the low moorland which is here particularly well developed has a general altitude rising gently from 250'-500' in the west to 1000'-1250' in the east. Its eastern margin is marked by a very sharp change of gradient, where, at between 1000'-1250', the steeper smoother slopes of the higher hills rise above it (see F. 5. and F. 17). To the west, it is terminated by the steep left bank of the River Cree, which drops abruptly from the edge of the moorland surface at about 250'-300' to 100'-150' on the holm land below. Further north and north westwards a marked break of slope between 250'-500' separates the low moorland surface from the lowland area at 100'-250', across which the lower stretches of the Minnoch-Trool rivers have cut their courses. This sloping surface is crossed by immature burns which rise on the lower slopes, or at the base of the higher hills, and, consequent upon the general slope of the moorland surface, radiate out to join the Trool and Minnoch or Cree Rivers. Where they cross the break of slope between 250'-500' they are in the process of cutting small but striking defiles some 10'-15' deep, while those which join the Middle Cree cascade over its steep left bank as waterfalls - the most prominent being the Grey Mare's Tail Burn.

The whole surface of this part of the low moorland area, excessively scoured, ridged, and broken giving, what might well be described as, an excessively mammilated appearance bears witness to severe glacial erosion at one time. Ice disgorging from the Loch Trool rock-basin (one of the main outlets for ice escaping from the Loch Doon gathering grounds further north) is believed to have moved west and south west, and eventually southward along the line of the River Cree. Certainly the graining of the land surface would appear to corroborate this hypothesis. One of the most striking results of this glacial erosion is to be found over the low ground, below 250', on either bank of the lower River Minnoch. Here innumerable, irregular, moor-covered knowes diversify the surface (see F. 18. and F. 58 photo (5)). While these vary in size, and often in shape, they are characterised by a general north-east - south-west trend, which coincides with the direction of strike of the Ordovician greywacke from which they are formed. Elongated ridges formed from a solid core of rock, and with here and there indications that their south-west ends, the 'stoss' ends, have been over steepened, shattered and truncated, they might well be called 'rock drumlins'.[1] Quarrying of the larger ones reveals a core of much shattered and fractured greywacke, whose outer surface is jagged and uneven and is covered by a layer, seldom exceeding 6" of rubbly irregular rock fragments, covered by a thin layer of peaty soil and supporting a moorland vegetation.[2] In size they range from a few feet to approximately 25' high with a maximum width of about 100'-200' and with slopes usually over 10° steep. They also vary considerably in density - a rough calculation giving something of the order of 50-100 per square mile: but this figure must only be regarded as an approximate mean since the intervening flats and hollows which separate them range in width from only a few to several hundred yards. Above the break of slope at 250'-500' (see F. 17) these so-called rock drumlins lose their separate identity and individuality and give place to an intensely ridged surface (see F. 58 photos (5) (6)) which rises gradually in altitude to about 1000'-1250', but retains to the end the marked north-east - south-west trend.

This trend or graining of the surface is modified and is less strikingly marked further to the south and south-west part of the low moorlands, particularly over that portion which lies

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[1] Pringle J., (1948) - See Plate V(b) where they are called 'rocky knolls'. Rock drumlin is here suggested because of their shape, and since they are formed of rock with a thin covering of soil and vegetation.

[2] (Despite their thin immature soil cover, these rock drumlins are alive with rabbits who seek a drier, if shallower habitat, than the intervening flats can provide).

above the left bank of the river Cree. Here, not only is the effect of glacial scouring less spectacular, but the resulting trend of ridges or furrows has swung round to a general north-south direction (see F. 15/16. (3b.). In doing so, the grain of the surface cuts across almost at right angles, and obscures to a large extent, the strike of the Ordovician rocks. The small immature burns, on the other hand, which flowing from east to west across this broken surface to join the Cree follow the direction of strike and in doing so impose a coarser more widely spaced Caledonian grain on the finer but more definitely marked north-south grain due to glacial scouring. The result is again a roughened mammilated surface which at close range presents a scene of apparent confusion and chaos. It is not until a vantage point is gained on one of the steeper slopes which rise above it that the general pattern and trend of the relief is clearly discernible - a trend clearly visible on aerial photographs also.

South of the Cordorcan Burn, and between it and the wider, glaciated, and well developed valleys of the Pulnee-Penkiln Burns (see F. 15/16 (3c)) the graining of the land gradually becomes more definitely Caledonian again (north-east - south-west) that is to say in alignment with the direction of strike of the underlying strata. Finally, west of the Penkiln-Pulnee Burns, and particularly over that area of low moors which lies directly to the north-west of the Bargaly Glen (see F. 15/16 (3d)) the combined effects of sub-aerial and glacial erosion are even more accentuated than in the former area.

Ice escaped from the Clatteringshaws Loch area and moved in a south-westerly direction, that is to say long the line of strike of the steeply dipping, often vertical, isoclinally-folded Ordovician strata. In doing so it must have picked out, or more probably accentuated, the difference between the harder and softer bands of rock. The result is an excessively 'ribbed' land surface whose Caledonian trend, from north-east → south-west, is as striking on the ground as on the aerial photograph (see F. 59 photo (7)). This trend is most pronounced, and has its greatest effect on landform, below a 1000' where the attendant ridging and furrowing of the surface has resulted in a considerable dissection and indeed obliteration of the general surface of the low moors, which, as in the former area, rises in altitude from 250'-500' to 1000'-1250'. Also, since this Caledonian ridging is continued on the sides of the higher hills to the north west up to, and even over, summits of 1500', the distinction between the low moors and the higher hills is not so clear, nor so evident, either from the point of view of vegetation or landform as in the former area.

The scale and intensity of ridging varies considerably within this sub-area. Two major furrows by their depth and alignment form major features (see F. 19 and F. 59 photo (7)). Firstly, that followed by the Palnure Burn whose upper course, in a steep-sided glacial valley at a level of about 400'-500', is separated by a breached rock barrier from its lower course which occupies an even more sharply pronounced 'U' shaped trough, the Bargaly Glen at 250'. The line of the upper course is continued by the slight furrow, some 200' above the bottom of the Glen, and is now followed by the line of the New Galloway - Newton Stewart Road (A712). Lying north-west and parallel to the Bargaly Glen but at a slightly higher level, 600'-800', is the second major furrow. Not as pronounced nor as continuous nor as uniform as the latter, it is nevertheless another well marked feature followed once by the Old Edinburgh Road and the Deil's Dyke and, in its deeper parts, occupied by a line of small lochs. This trough is most highly developed around the Black Loch where steep slopes (the south-east facing slopes are considerably ragged and almost vertical) cut abruptly some 150' below the general surface of the ground, and where the flat bottom of the hollow is some 200-300 yards wide.

North west of the Black Loch furrow, particularly in the area drained by the Grey Mare's Tail Burn, the Caledonian ridging occurs in its most striking and most finely developed form. From about 750'-800', above the Black Loch, to 1000'-1259' on the lower slopes of Millfore (2150')[1], over a distance of approximately a mile, there are at least four well-marked major ridges, distinctive enough to be known to the local shepherds, but not marked on the Ordinance Survey maps, by individual names (see F. 19). Depending on the local dip of the strata from which they are carved, they vary in form from the symmetrical hog-back to the asymmetrical cuesta-like ridge. Their slopes are steep,

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[1]Map ref: 478754

from 10°-30°, longer (250'-150') on the down hill, south-east facing side, shorter (50'-100') on their up-hill north west facing side. Between these major ridges and indeed scouring across them also, are innumerable smaller ridges (25'-50') rising sharply and steeply from intervening flats and hollows.

Cutting deeply at right angles across this Caledonian trend are the melt water gorge of the Tonderaghee Burn, and the only other major tributary of the Bargaly Glen, the Grey Mare's Tail Burn. The latter, however, together with the other burns, tributaries of either the Dee or Penkiln Burn, which drain the remainder of this sub-area have a general north-east - south-west alignment and tend to accentuate further the trend of the relief. Indeed, in the area drained by the Grey Mare's Tail and its tributaries, with the burns meandering and sluggish, across the ill-drained flats or cutting miniature falls and defiles southwards through the steep ridges and knowes, a beautifully marked rectangular drainage pattern, if only on a local scale, has been developed.

The combined effects of sub-aerial and glacial erosion, and the present drainage pattern have produced a land surface even more diversified and broken than in the previous sub-area described. If, however, on the basis of differing scale, and trend, of its erosion, the area of low moorland can be subdivided into two slightly different physical habitats, it is not a division which is reflected in the vegetation. A similar vegetation covers and unites the two sub-areas, since the effect of the relief features on the vegetation is in both cases identical. In both, the extreme micro-dissection of the ground is reflected in a minute compartmenting of the vegetation, dependant basically on considerable variations of slope within relatively small areas. The ridges and knowes, with their steeper slopes are better drained: they carry a relatively dry type of vegetation: they may be covered by a layer of thin peat or peaty soil, (seldom exceeding 6" in depth) which may in turn overly solid ice-scraped rock, or, as in many instances, a rubbly angular to sandy mineral soil. Some of the knowes, or parts of them, on the other hand, are completely devoid of vegetation or soil, and present the smooth, striated, bare rock surfaces of roches moutonnées. The intervening flats and hollows which may, or may not, be either artificially or naturally drained carry a much wetter, a boggy vegetation, on peat whose depth ranges from a few to several feet.

Below approximately 750'-850' the flats and hollows are most commonly occupied by a Molinia - Myrica gale (see F. 59 photos (8), (9) and F. 60 photo (10)), (a facies of the Molinia flow)[1] association, especially where there is just sufficient slope to allow natural drainage - or where artificial drainage has been effected at one time or another. As in the Molinia flow association, the vegetation may be completely dominated by either

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1 Where, however, the flats are extensive as around the Black Loch they have been classified and distinguished separately within the Molinia flow association; but over most of the areas under consideration the patches are too small to be separated and classified individually.

(1) Molinia caerulea, usually strongly tufted, (2) Myrica gale, in wide patches and often growing at the edge of a flat at the junction between it and the adjacent steep-sided knowe, (3) Juncus articulatus, dominant especially in areas of relatively rapid drainage and abundant water supply or, (4) a combination of all three. On other flats, however, the association is of a more mixed character, a typical sample revealing,

Molinia caerulea	(d).......tufted
Myrica gale Juncus articulatus	(s-d).....or in 'local' patches
Sphagnum spp.	(a)
Scirpus caespitosus	(f)
Erica tetralix	(f)
Calluna vulgaris	(f)
Narthecium ossifragum	(o)......usually present although not abundant: characteristic.
Eriophorum spp.	(o)
Carex spicata	(o)

While an association dominated by Molinia caerulea and Myrica gale is prevalent on the flats and hollows below the arbitrary limit of 750'-850', it is not unusual to find other patches dominated by yet another wet moorland species, be it Scirpus caespitosus or Eriophorum vagination. Over some of the wider and more extensive flats which separate and inter-penetrate the rock drumlins on either side of the lower Minnoch River, especially over those whose gradient is negligible and whose drainage is poor, Scripus moor may be dominant and reveal the following composition:-

Scirpus caespitosus	(d)
Erica tetralix	(s. d. to f)
Calluna vulgaris	(usually f)
Molinia caerulea	(f)...although small and not tufted.

Sphagnum spp. (a)... on peat of considerable depth and reputed to be of as much as 12'-15'.

Many of these lower, flat, peat-covered areas have been, and still are cut for fuel; where this has occurred, the slightly lower ground from which thicknesses of 1'-2' of peat have been removed, and in which water is collecting and stagnating, is often covered with pure Sphagnum (spp.) or Sphagnum (spp.) associated with Eriophorum (spp.) and Calluna vulgaris. Eriophorum (spp.) however does not often occur as a wide-spread dominant within the area surveyed - except in localised patches. One of these occurs over a fairly wide area, too wide to be ignored of flat, unbroken ground above the east bank of the River Cree, where on recently drained peat of some 2'-3' in depth Eriophorum vaginatum was practically completely dominant.

Separating, and alternating with, the flats and hollows are the innumerable ridges and knowes, the range in size, slope, and form of which defy a reasonable generalisation. They are certainly better drained, and carry a drier, or dry vegetation cover which may be dominated by:-

(1) Bracken.[1] particularly on those knowes which have a thin or no peaty layer and have a sub-soil of angular mineral debris. A typical sample reveals the following composition:-

Pteridium aquilinum	(d)
Agrostis spp.,	(a)
Festuca ovina	(f)
Galium saxatile	(f)
Blechnum spicant	(o)
Potentilla erecta	(f)
Calluna vulgaris	(o)

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1 See page 107 for fuller consideration of this species.

(2) <u>Dry heather moorland</u> on thin dry fibrous peat, and with the following composition:-

Calluna vulgaris	(d)
Agrostis spp.,	(f)
Nardus stricta	(usual)
Galium saxatile	(")
Blechnum spicant	(o)
Scirpus caespitosus	(o)...... usually scattered

(3) <u>Mixed (wet) moor</u> in which -

Calluna vulgaris
Scirpus caespitosus
Molinia caerulea (non-tufted)

together, are often strikingly co-dominant to the exclusion of all other species and occurring in equal amounts, form a low-growing moorland cover, but frequently diversified by other species such as:-

Nardus stricta
Deschampsia/Aira flexuosa
Pteridium aquilinum
Potentilla erecta
Galium saxatile
Festuca ovina

on the one hand, or

Erica tetralix
Sphagnum spp.,

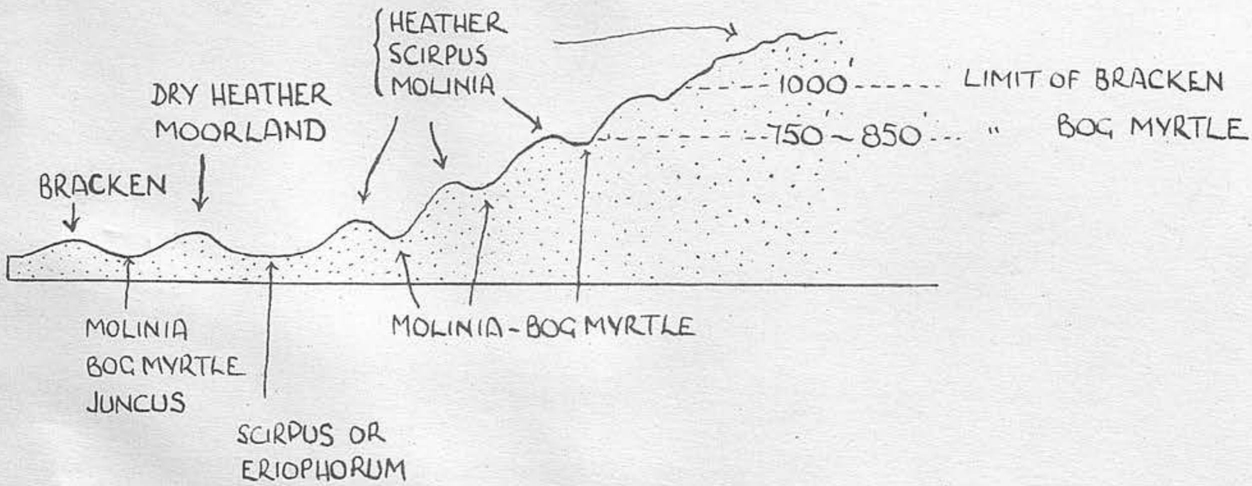
on the other, according as conditions are relatively drier or wetter.

Above 850', or even 750', Myrica gale is absent, Molinia caerulea loses its tussocky habit, Pteridium aquilinum is less vigorous and less dense, and the vegetation of the low moors assumes a slightly more uniformly mixed character. Certainly

DIAGRAM 2.

DIAGRAMMATIC SUMMARY OF 'FACIES' OF MIXED WET MOORLAND.

(NOT DRAWN TO SCALE).



the ridging of the ground surface, though still present, is less intense and the flats and hollows less wide and continuous. Where slopes are particularly steep (over 20^{o}) dry heather moorland, dominated by Calluna vulgaris, predominates. But over much of the area covering ridge and furrow alike, a vegetation composed of the more even mixture, noted previously, of Calluna vulgaris - Scirpus caespitosus - Molinia caerulea is widespread, although under the influence of local variations of slope, one or other of these three species may gain temporary dominance accompanied by a greater variety of either drier or wetter associates, as the case may be. Diagram 2 (opposite) attempts to summarize diagrammatically the relationship of these various 'facies'. All these variations in the specific content of the mixed wet moor, which occur and repeat themselves from over 200' up to 1250', or even 1500', in some cases, form in fact, separate and often distinct associations which could be plotted and represented individually probably on a scale of 6" to a mile and <u>certainly</u> on one of 25" to one mile. Here they must be regarded as sub-associations, '<u>facies</u>' of the one composite association, mixed wet moor. There is little doubt that these numerous facies, intermingled and interwoven, reflect and are dependent upon the rapid variations of slope and resulting variations in drainage which are so characteristic of these low moors. Attempts to investigate what, if any, correlation might exist between different 'facies' and certain degrees of slope by exact measurement gave no satisfactory results and had to be abandoned in view of the detailed and time taking nature of such work which was out of proportion to the demands of this esentially primary survey.

A summary of the limited number of slope measurements which were taken is given in the following table:-

Sub-Associations or 'Facies'	Molinia - Myrica gale	Dry heather moorland	Bracken	Molinia - heather-Scirpus
Range of Slope	10°-19°	18°-29°	15°-23°	11°-30°
Most prevalent Range	10°-11°	23°-25°	-	-

These figures are based on measurements, made largely at random, over widely scattered parts of the mixed wet moor association - but measurements not considered numerous enough to be really representative of the area as a whole.

They do however corroborate and illustrate certain observations made during the course of field study. First, that the range of slopes over which any one particular sub-association or 'facies' occurs is often quite wide, and second, that the range of slope over which the Calluna-Molinia-Scirpus facies occurred was noticeably wide. This particular facies, which may well be considered the most typical, the mean of the mixed wet moor, becomes more prevalent and more widespread on the higher parts of the low moors; between 850' to 1250'/1500' it is found clothing slopes which one might reasonably expect to, and which do at lower altitude, support a drier type of vegetation. It is tempting to account for this in terms of increasing rainfall. That the type of vegetation a given slope or range of slopes will support depends also on the climatic conditions, and in particular on the amount of rainfall must certainly be admitted. However the actual degree, or range of degrees, of slope which will support a given association under given rainfall conditions is a nice problem, the solution of which might do much to explain more clearly the complexities of this mixed wet moor. Certainly, a more detailed and systematic measurement of the slopes over which the main facies occur would give more satisfactory results than indicated by those in the previous table, but in view of the many other imponderable factors which must also be taken into account - factors such as moor burning, peat cutting, grazing, draining, which cannot be quantitatively assessed, it is doubtful whether any direct correlation between the degree of slope and specific content of a particular association could in fact be satisfactorily established over such a restricted area.

The broken surface of this low moorland area, which has so effectively split the vegetation into a patchwork of facies or sub-associations and has yet, at the same time, allowed and laid the basis for their unification into one major association, has made attempts to relate the mixed wet moor to the other types of vegetation mapped, difficult. It was classified originally as a wet moorland association in view of the large proportions of wet moorland species within it, but further consideration of its content and character emphasises its essentially transitional nature. It is composed partly of dry moorland associations and partly of wet moorland associations, a result of the land surface over which it occurs. Also, the Molinia-Calluna-Scirpus facies which it has been noted, is, at slightly higher altitudes, one of the most characteristic and most widespread members of the mixed wet moor bears in form and composition a close resemblance to Fraser's transitional Scirpus-Calluna-Molinia moor,[1] with its diffusely-distributed, untufted, short growth of these three species. He regards it as a transitional stage towards the climatic climax of Western Scotland, Scirpus high moor. Whether this is the case here or not is debateable. Certainly the Scirpus-Calluna-Molinia facies occupies a transitional position altitudinally, in space if not in time, between the lower-lying, strongly-tufted Molinia flows and the Scirpus moor which becomes dominant at higher altitudes, a position one might be tempted to infer where rainfall and drainage conditions inhibit the development of Molinia flow and where rainfall is not great enough for the establishment of the climax. However, the fact cannot be overlooked that this particular form and composition may well have been established by moor burning which, as Anderson[2] notes, may give such transitional

1 Fraser, G. K., (1933) p. 21

2 Anderson, M. L., (1950) pp. 41-42

communities a certain permanency.

Evidence and comparisons from within this particular area of low moorland are conflicting. South of the Bargaly Glen, the mixed wet moor association is continued over the roughened, ridged, and knowed surface of the largely metamorphosed Ordovician rocks, which, rising from 250' - 1000'/1250', ring the smoother, steeper slopes of the granitic intrusion of Cairnsmore of Fleet. The effect of landform on the vegetation cover is similar to the former low moorland area and the diverse pattern of sub-associations is repeated. It is worth noting however that, on Blair Hill (600')[1], Clanery Hill (700')[2] and Knocktun (900')[3] below Cairnsmore, the Scirpus-Calluna-Molinia facies is strikingly well developed. In some cases, short non-tufted Molinia and abundant, diffusely-scattered Scirpus were dominant, accompanied by Calluna, short, scattered, and not quite so abundant as the two former species; in other cases, a somewhat longer vegetation, dominated still by Molinia but with Calluna sub-dominant and Scirpus frequent, prevails. The noticeably uniform and at times almost sward-like appearance of the vegetation is undoubtedly due here to regular and heavy burning which has in addition destroyed the Sphagnum layer. Indeed, in places, wide and completely bare, although considerably puddled, patches of peat break the continuity of the plant cover.

Again, to the north of Loch Trool, the southern end of the

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1 Map reference /478625

2 Map reference /490630

3 Map reference /508638

central granitic ridge of the Loch Doon complex was investigated (see F. 15/16 (5)). Here, between Loch Valley and the Glenhead Burn, steep slopes bound a low, (1000'-1250'), glacially roughened, lake-dotted plateau, limited to the west by the Gairland Burn and to the east by the higher ridge of Craiglee, it presents a desolate stretch of moorland. Its surface is ridged from north to south by uneven knowes or smooth, bare, striated roches moutonnées and a disorder of angular granitic blocks of varying size diversify the surface. A peat cover which varies from a few inches to several feet supports a relatively uniform and certainly widespread representative of the Calluna-Scirpus-Molinia facies with:-

Molinia caerulea	(d)	.......non-tufted
Scirpus	(d to v.f.)	.both tufted and diffuse.
Calluna vulgaris	(v. f.)	
Erica tetralix	(f)	
Sphagnum spp.,	(a)	.......forming a fairly continuous ground layer.

While its composition is very similar to the Scirpus-Calluna-Molinia facies of the Cairnsmore area and of the low moors, it is of a slightly longer, of a less even sward-like form and is accompanied by a greater variety of other species. In these latter two respects it would appear to have more in common with Anderson's Sphagnum of Calluna moor - a transitional community due to burning. This conflicts with the view that, on the basis of field work in the Newton Stewart area, the even sward-like facies dominated solely by Calluna-Molinia-Scirpus is a transitional temporary stage due to burning, while the more uneven longer and more mixed facies of the granitic plateau to the north might represent a true transitional stage to the climatic climax imposed by its intermediate position altitudinally.

Whatever the status of this distinctive facies within the mixed wet moor association may be, there is little doubt that the distribution and the composition of this highly varied and complex association is closely related to, indeed dependent upon the, one might truthfully say, lacerated nature of the glacially scoured surface of the low moors: and covering this particular landform it occupies a transitional position, altitudinally, between the Molinia flow of the lower valley floors and the Scirpus moor which dominates the wet moorland at greater heights.

<u>Scirpus moor</u>. In contrast to the mixed wet moor Scirpus moor has a more constant and more uniform botanical composition and its recognition on the ground as a distinct association is facilitated, especially in late summer and early autumn, by the copper-red colour imparted by the dominance of Scirpus caespitosus.

Apart from the isolated and restricted patches which it was noted occurred among the mixed wet moor, Scirpus moor is more prevalent and widespread at higher altitudes, usually over 1250'-1500', where it becomes the characteristic and dominant type of wet moorland association. Over ill-drained areas of gentle gradient, and on often deep black and usually fibrous peat it reveals the following typical composition:-

Scirpus caespitosus	(d)......	usually fairly strongly tufted and often long.
Calluna vulgaris	(sub-d)..	at times - although usually scattered liberally through the association.
Erica tetralix	(f)......	sometimes sub-d. Replacing Calluna vulgaris where very wet.
Empetrum nigrum	(f)	
Sphagnum spp.,	(f)......	(abundant in ground layer)
Eriophorum spp.		usual although not profuse or particularly abundant.
Molinia caerulea	(v. o.)	
Carex spp.		

with <u>occasionally</u>, drier species such as -

Potentilla erecta
Vaccinium myrtillus
Hypnum scheberi
Polytrichum commune

In this form it occurs as the dominant wet moorland association over two contrasted physical habitats within the Newton Stewart area (see F. 15/16 (2. 2) and (4)).

(1) <u>First</u>, it is found at altitudes of over at least, and usually exceeding, 1200'-1500', in the north-west of the area (see F. 15/16 (2,2)). The ridging of the land surface which is so pronounced and so characteristic a feature of the low moorlands is maintained, if in a less intense and somewhat modified form, over the slopes and summits of the steeper and higher hills which rise above it, that is, up to and over 1950' - 2000'. This is particularly noticeable over those hills which lie directly south of Loch Dee. Here steep, usually convex, slopes give place over 1500' to broad spurs and ridges, which

flatten out to a gently inclined summit level between 1500' and 1750'-1900', and above which the higher and more restricted summits of Curlywee (2212')[1] and Millfore (2150') rise relatively abruptly (see F. 60 photos (11), (12), (13),). The lower summits and bounding slopes are ridged and mammilated in a north-south direction, a trend further emphasised by the coarser grain imparted by the north-south drainage of the White Laggan, Black Laggan and Green Burns, all of which occupy valleys bearing considerable evidence of glacial modification. Here, in contrast to the low moorland areas, the grain of the surface practically obscures, particularly on the north-facing slopes, the Caledonian strike of the underlying Ordovician strata and would appear to support the assumption that at one stage during the glaciation of the area, ice spilling out and overflowing from the Loch Dee gathering grounds, over rode these higher hills and escaped southwards, no doubt to join the ice stream moving from the north-east and following the line of the Bargaly Glen.[2]

It is on these gently inclined, although considerably roughened, summits between approximately 1500'-1750', with their heavier rainfall (over 70" in contrast to 50" - 65" over the low moors) that Scirpus moor in its purest and finest form, and characterised by a marked dominance of Scirpus caespitosus, attains its widest extent. The furrowing and ridging of the

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1 Map reference /455770

2 Charlesworth, J.K., (1926)a.

ground however breaks, to a lesser or greater degree, its spatial continuity and, consequent upon the glacial scouring, steep-sided knowes and ridges carrying either heather or, more frequently, dry grass moorland intervene. The result is that its distribution on the ground is inclined to be patchy, a fact which the map has endeavoured to indicate.

While it is certainly a noteworthy fact that Scirpus moor dominates these higher wet moorland areas, its significance is not absolutely clear. Whether its formation is due primarily to topography (basin moor) giving under conditions of high rainfall poor drainage conditions or whether it represents the climax (climatic moor) type of moorland, is debatable. Its finer development in the hollows and areas of flat or very gently inclined ground between the upstanding ridges suggests the former; also, although it occurs within that area of Britain where, according to Fraser[1], climatic moor constitutes the main stable soil type, whose ultimate (climax) stage in the west and north-west of Scotland is Scirpus moor, its composition does not conform entirely to that of his typical Scirpus association.

(2) Second, Scirpus moor occurs in yet another slightly different habitat (see F. 15/16 (4)) and at a somewhat lower altitude 1250'-1500'. On low, ill drained 'cols' (see F. 60 photo (14)) which separate the north-facing spurs of the 'white hills' and above the inner edge of the low moorland surface and

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1 Fraser, G. K., (1933) pp. 9-11.

on what may be a glacial step, a considerable thickness of black fibrous peat has accumulated on "plugs" of glacial material. This peat which is hagged, consequent upon the headward erosion of those burns which, rising at the base of the higher hills, have incised themselves into the soft drift material, carries Scirpus moor similar in composition to that found in the former habitat. There is however a greater abundance of Calluna vulgaris, which at times is sub-dominant or even dominant, especially on the outer and more intensely hagged areas of the peat cover which are rapidly drying out. The convex, slightly domed surface of the peat strengthens the suggestion that in this case the Scirpus moor has developed as a consequence of impeded drainage - drainage not only impeded but probably diverted by glacial deposition.

CHAPTER V.

Vegetation of the Newton Stewart Area (contd.) - Dry Moorland.

Dry Moorland In contrast to the wide extent and variety of wet moorland of one kind or another, dry moorland occupies a relatively minor position in the Newton Stewart area. It is associated most commonly with the steeper slopes of the higher hills, and the well drained knowes and ridges of the low moors, but in both cases, especially the latter, its continuity is continually broken by larger or smaller stretches of wet moorland. Three groups can be recognised and defined, only two of which however are of an extent wide enough to be mapped:-

Summit Vegetation caps most of the hills, (see F. 15/16 (1a) and (1c)) above approximately the 2000' contour line and is the nearest approach to an Arctic-Alpine vegetation[1] in the Southern Uplands. It is distinguished primarily by its form - a short, springy turf of low growing, fine leaved grasses, mosses and lichens - from the mixed grass moorland, into which it grades below 2000' and with which it has the majority of its species in common. Not quite so rich in grass species, however, it possesses a greater abundance of mossess and lichens. While its percentage content is inclined to vary slightly from one summit to another the following analysis is representative of the association as a whole:-

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1 Tansley, A.G., (1949a) pp. 780-796.

Festuca ovina var. vivipara	(d)	....the most usual dominant.
Vaccinium myrtillus	(f)	...in places co-d with F. ovina.
Hypnum scheberi Rhacomitrium lanuginosm	(á)	...and sometimes (d) forming a continuous ground layer.
Lichens. Cladonia rangifera	(f)	
Nardus stricta	(f-a)	...occurs in, but is not characteristic of this association. It grows in widely separated tufts near the lower margins of the association: its length and colour are in conspicuous contrast with the surrounding low growing turf. (see F. 60 photo (13)).

also frequent near the lower margin of the association are:-

Galium saxatile	(f. a.)
Potentilla erecta	(o)
Deschampsia/Aira flexuosa	(o)
Agrostis spp.	(o)
Juncus spp. (compressus and squarrosus)	(o)
Carex spp.	
Lycopodium selago	(o-f) occurs most abundantly on the summit of Cairnsmore and is to be noted as the only really <u>characteristic</u> species that can be designated as 'Arctic-Alpine'.

This summit vegetation attains its finest and most characteristic form and development on the wide plateau-summit of Cairnsmore, where F. ovina, V. myrtillus, together with mosses and lichens are the predominant species in the fine close carpet. On Millfore it is however of such a mixed and varied character that its separation from the surrounding mixed grass could be open to criticism. The summit is barely over 2000' and a representative sample of the vegetation reveals -

Nardus stricta Vaccinium myrtillus	(co-d)
F. ovina var., vivipara	(a)
Calluna vulgaris	(f)
Hypnum scheberi	(o)
Lycopodium selago	(v. o.)

It might be noted here that Vaccinium myrtillus is not abundant in the Newton Stewart area as a whole. It is most commonly found in any quantity above, at least, 1500'-1750' and only attains abundance within the summit vegetation where it is small and scattered.

The association, summit vegetation, as a whole grows on a thin, usually black and crumbly peaty soil seldom exceeding 1" in depth, lying either directly on bed rock or, as on Curlywee, on a covering of angular weathered fragments (see F. 60 photo(11)). On the more extensive plateau summit of Cairnsmore of Fleet, the peat cover varies markedly in depth, and occasional isolated clumps of deeper and wetter peat rise above the general smooth surface and carry Sphagnum spp. and associated species such as Eriophorum vaginatum and Scirpus caespitosus. While these clumps <u>may</u> indicate a formerly thicker peat cover of which these are remnants, it is more probable that considerable exposure to high wind force prevents an extensive development of peat and that stripping by wind results in a cover of unequal depth.

The extent and development however of this summit vegetation in the Newton Stewart area is limited - there being few hills, with the exception of Cairnsmore with extensive summits over 2000'. Its distribution and occurrence here would appear to reflect the climatic rather than any specific landform feature. The relatively low altitude at which it is found, and at which it begins to develop, may well be correlated with the severe exposure especially to west and south-west winds, to which these hills are subjected.

Fundamentally the classification and delimitation of the association are based on its form and, in late summer and autumn, its darker green colour, both of which characteristics contrast with the dry grass moorland into which it usually merges below 2000' (see F. 60 photo (13)).

Dry grass moorland[1] or heath, the predominant association of the shepherd's "white" hills, is, in this area, the most important and widespread member of the dry moorland. It is dominated in its most typical state by a fairly even mixture of the following grasses:-

Nardus stricta, Agrostis spp., Festuca ovina	(co-d)
Anthoxanthum odoratum	(a) often (co-d)

whose proportions vary slightly from one locality to another giving one, particularly Nardus stricta predominance at times over the others. The extent or significance of such variations however do not appear to justify on this scale any sub-division of the association on the basis of one particular species. Many other typical 'heath' or 'moorland' species accompanying these grasses, in particular -

Potentilla erecta	(f)	
Galium saxatile	(f)	
Calluna vulgaris	(f)	- sometimes (d) or (co-d) locally.
Vaccinium myrtillus	(o-f)	increasing in amount with increasing altitude.

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1 c. f., Anderson, M. L., (1950) p. 37 and Tansley, A. G., (1949a) pp 506-514.

Hypnum scheberi	(f)
Polytrichum commune	(f-a)
Juncus squarrosus	(f)
Molinia caerulea	(v. o.)
Seiglingia/Triodia decumbens	(v. o.)
Campanula rotundiflora	(v. o.)
Blechnum spicant	(o.)

Juncus articulatus — forms wide dense patches, some several square yards in extent, on ground flushed by spring water, or commonly beside a dyke which has acted as a local dam to water flowing downhill.

Except on the flushed soils accompanying these local patches of Juncus, the mixed grass moorland is usually associated with a peaty soil, inclined to be fibrous, well drained and with a maximum depth of 6". In contrast the flush soils are extremely wet, black to grey in colour with a high content of mineral matter forming a black mud which has a peculiar and characteristic foetid smell.

The grass moorland association reaches its widest extent and greatest dominance on the steep (usually over 20°) well drained, and generally smooth, convex slopes of the Larg-Lamachan-Cambrick line of hills, (see F. 15/16 (1a) and F. 61 photo (15)) which appear, in contrast to the glacially-roughened surface of the low moors from which they rise abruptly, to have retained some characteristics reminiscent of the dissected plateaux of the Eastern Southern Uplands. Only a remnant, however, of what may have been a wide smooth plateau has survived. Both the north and south-facing slopes of Larg and the north-facing slope of Lamachan hills have been over steepened by incipient corrie formation which in places has reduced the summit to a smooth narrow edge and has resulted in considerable screeing on the over steepened and still unstable slopes below. (see F. 60 photo (13) and F. 61 photo (15)). Even more striking is the broad low corrie between the north face of Curleywee and Bennanbrack[1] and also the steep left bank of the Glenhead Burn where, in both cases, glacial over steepening has resulted in concave slopes.

The other 'white hills' (see F. 15/16 (1b)), Borgan,[2] Craignaw[3], and White Hill[4], possess, in general, the same convexity and, above all, steepness of slope - but situated marginally to the higher Larg-Lamachan-Cambrick ridge, and at a slightly lower altitude of 1750'-1500', they do not appear to have escaped quite so successfully the effects of glacial erosion. They have an uneven surface broken by a Caledonian ribbing (see F. 60 photos (12)(14)) which becomes more marked on their south-west slopes. In addition to the north-east to south-west graining, White Hill (see F. 57 photo (3)) is scoured in a north south direction, a result, in all probability, of ice over-riding this area from the gathering ground north of Loch Dee. However although this ridging interrupts the smoothness of the slopes, and often results in local patches of Scirpus moor on thick peat especially on the summit of these hills, the latter are not numerous enough, nor sufficiently extensive, to break the continuity

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[1] Map reference /435774

[2] Map reference /404760

[3] Map reference /406770

[4] Map reference /458775

of the grass moorland which dominates them - a dominance which would appear to depend primarily on the steep and above all well-drained character of these hill slopes. The prevalence of steep slopes within the relatively compact area of grass moorland occuring on the central hills is illustrated on the slope analysis (see F. 17). Despite the over-generalisation of natural conditions, arising from the scale on which this diagram was constructed, it nevertheless emphasises the more outstanding slope conditions i.e. the marked break of slope at approximately 1000' between the base of these hills and the lower moorlands to the west, and the greater extent of steep slopes on the central group of hills.

The classification of the vegetation of the steep slopes of Millfore and Drigmorn[1] as supporting an isolated patch of dry grass moorland to the south of the main area mapped must, it should be noted, be viewed with extreme caution. Although mapped as dry grass moorland, there is here not only a higher percentage of Calluna vulgaris than on the previously described hills but a much greater and more definite ridging of the land surface, giving rise in the intervening flats to a more extensive development of Scirpus moor. On the basis however that over a considerable area downslope of, and radiating from, the summit of Millfore, dry grass moorland occupies perhaps the greatest percentage of the surface - it has been classified as such. But its boundaries are less definite, and much less clear-cut, than

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1 Map reference /457747

the vegetation map might suggest, because of the more broken nature of the surface as compared with the hills to the north of it. On the one hand however, it is too small a patch to allow any useful sub-division on this scale of 1:25,000, while on the other hand, it is too large an area to be ignored and merely lumped with the surrounding vegetation. It epitomises one of the major problems confronting the worker faced with the task of classifying a patchy vegetation cover into reasonably accurate and not too generalised units. It is a problem which the individual worker can only resolve, in the case of such a reconnaissance survey, by visual observation and personal judgement, and the result, where not qualified by detailed quantitative measurements, must necessarily be an arbitrary one.

The occurrence and amount of Calluna vulgaris and other typical moorland species within this mixed grass moorland varies considerably and suggests that, as in other parts of Scotland, it may well be a sub-seral association resulting from the over-grazing and consequent degeneration of dry heather moorland. The steep, smooth, and generally convex, slopes over which it attains its greatest extent and dominance provide the ideal habitat for dry moorland. The use of these drier hill slopes of, it must be stressed, relatively small extent within this particular area, particularly for summer grazing no doubt contributed largely to the formation and maintenance of the dry mixed grass moorland.

<u>The dry heather moorland</u> association dominated entirely by Calluna vulgaris and so well developed over wide areas in the east, only

attains local dominance outside the area mapped as dry grass moorland. Its area is never great enough to be shown on the map and for that reason it has been necessary to incorporate it with the mixed wet moorland association.[1] The nearest approach to a wide extent of dry heather moorland associated with a well defined habitat, is that found on the steeper slopes of Cairnsmore of Fleet between 1000'-1750' and which, because of its patchy nature, has been classified as -

Mixed heather and grass moorland: At about 1000' the steep, smooth, rounded, mass of the granite intrusion of Cairnsmore (see F. 15/16 (1c)) rises above the glacially eroded Ordovician sediments and provides steep enough slopes for the development of a dry moorland association of the following characteristic composition:-

Calluna vulgaris	co-d
Vaccinium myrtillus	
Nardus stricta	
Agrostis spp.	

together with

Empetrum nigrum	(f)
Festuca ovina	(f)
Deschampsia/Aira flexuosa	(a)
Molinia caerulea	(o)

growing on a generally poor and thin peaty soil. The continuity of this association and its constancy of content are however far from complete. The weathering of this massive rectangularly-jointed granite has resulted in a profusion of large and often rectangular blocks of this rock over and down even the steepest

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1 See page 86

slopes giving a virtual 'felsen-meer'[1]. It was noticed that many of the larger (4' x 4') granitic boulders were sufficient to break the slope and allow the collection, and formation of raw peat carrying a bog vegetation, on their uphill sides, and signs of frost shattering and heaving of the blocks near the summit indicated that, in spite of a relatively well-developed vegetation cover, these steep slopes are still in a state of instability. Such factors must no doubt contribute to the mixed nature of the vegetation and accordingly make its classification difficult and again arbitrary.

Finally cutting across both the wet and dry moorland associations alike is the ubiquitous
Bracken fern (Pteridium aquilinum) whose approximate upper limit of growth is indicated on the vegetation map (see F. 12). The occurrence and composition of the bracken dominated association as a facies of the mixed wet moor has been noted previously[2]. While the essentially patchy nature of its distribution militates against any attempt to map it as an individual association on a small scale, its prolific, abundant, and widespread growth in this area cannot be ignored.

With its upper limit of growth at approximately 1000' and with its virtual exclusion, by reason of excessive moisture and lack of adequate drainage from the pure Molinia flow, it is

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1 Geomorphological term for boulder strewn surface: a 'Rock Sea'

2 See page 85.

confined practically entirely to that area covered by mixed wet moor. Nowhere was it observed growing much above 1000' ... a limit also recognised by the local foresters. This altitude however, which has been used to define the upper limit of bracken growth on the vegetation map must be considered its <u>maximum</u> upper limit throughout the area as a whole. In many instances, due to the deterioration of local conditions of drainage, slope, or exposure, it extends no higher than 850' or even 750'. But fluctuations in its upper limit are of such variable occurrence and are of such restricted extent, and since these reveal no general or significant pattern, they did not appear to justify any detailed representation on the map. Nevertheless, it is true to say that bracken probably attains its maximum profusion and luxurance of growth below 750'-800', above which altitude it becomes noticeably sparser and more open, as well as smaller.

Below a 1000', the primary and essential requirements for luxuriant bracken growth[1] - a depth of porous, well aerated, freely drained soil of at least 6" are satisfied most commonly over the low moors.

The intensely ridged surface provides freely drained slopes on the steep sided knowes, or on the more extensive steep slopes which bound the deeper valleys. In all cases weathering of the underlying bed rock together with adequate drainage have produced the characteristic 'bracken soil' in this area, ½"-1" of dry fibrous peaty soil (sometimes absent and on better sites

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1 Tansley, A.G., (1949b) pp. 163-166.

replaced by a fine loamy soil) over at least 6" of brownish sandy, gravelly or angular mineral fragments, bound together with a sticky clayey matrix with a considerable organic content.

The steep-sided knowes and the well-drained banks of the numerous burns provide admirable sites. The bracken is sometimes mixed with either heather or grass or is so completely dominant as to exclude all other species. Growth is most luxuriant on the lower slopes of the knowes thinning out or even absent on the crests, and terminating sharply at the edge of the adjoining ill-drained flats. Where a generally low ridging of the surface replaces the more sharply defined knowes, bracken appears to take advantage of every slight inclimation of slope, the trend of its vivid green patches picking out the grain of the surface. On the more extensive steep slopes which, for example border Loch Trool and the Bargaly Glen it is rampant, often clothing the entire slope up to at least 800' and often completely dominant. Though defying even a general approximation, the percentage area of the surface below 1000' covered by bracken is particularly and noticeably high. Indeed it has been voiced by a local shepherd[1] who has spent most of his life within this district, that within his experience and in his estimation bracken in the Newton Stewart area has shown no appreciable extension within the last twenty years. He even suggested that it had attained its maximum extension.

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[1] Mr. Spiers (Craignell) who possesses considerable knowledge of hill plants and local conditions in the Newton Stewart area.

Second only to the abundance of bracken in this area is its striking luxuriance of growth. Especially at lower altitudes, and on a good depth of well-drained mineral soil such as often occurs at the sides of those burns which are digging into glacial debris, bracken grows densely to heights of 4'-5', or over, and may form really impenetrable 'thickets'. This luxuriance may well reflect not only the abundant rainfall and high humidity, but the generally mild winter conditions.[1] The decrease in its luxuriance with increasing altitude and its absence over 1000' may arise from the high degree of exposure to which the area is subjected. On the other hand in more sheltered valleys there are no noticeable variations in its upper limit to strengthen this suggestion. Indeed along the slopes of the Bargaly Glen, subjected frequently to the high wind force consequent upon the funnelling of the prevailing wind, the vigour and altitude to which bracken growth appears unaffected. Also the degree and height of slopes, and the ridging over the whole area is so variable as to make extremely difficult any attempt to assess the effect of exposure on the upper limit of bracken growth. And even the well-worn dictum, repeated time and time again by farmer and shepherd, that its growth is more luxuriant on south than on north-facing slopes is not always borne out in the field for much the same reasons.

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[1] Suggested that this also accounts for the abundance of rabbits.

SECTION III

THE WANLOCKHEAD AREA.

CHAPTER VI

The Geographical Introduction to the Wanlockhead Area.

Structure and Relief and Landform. The second survey was undertaken in the Wanlockhead area (see F. 20) some thirty miles directly north-east of Newton Stewart. A compact block of hill country conveniently bounded by the rivers Clyde and Nith to the north-east and south-west respectively and by their tributaries the Crawick and Duneaton Waters to the north-west and the Carron and Potrail Waters to the south-east, it affords a reasonably representative sample of the maturely dissected Central Southern Uplands.

This area differs geologically from that of Newton Stewart in the absence of great igneous intrusions, in its proximity to the Southern Upland Boundary Fault which results in a greater predominance of Ordovician rocks and in the presence of younger sedimentary strata around its periphery. The main characteristics of rock type and structure are fundamentally the same (see F. 21) - the prevalence of the hard fine-grained gritstone (greywacke) and indurated shales - the occasional strata of coarse conglomerates - lenticular inliers of black shales, mudstones and cherts attaining a width of extent and outcrop only where they have been concentrated by close folding and subsequently exposed by denudation - a complex and intense folding of the component strata resulting in their either vertical or very high dip and a dominant Caledonian strike from north-east to south-west.

The uniformity of the Ordovician shales and greywacke is, however, interrupted in this area by conspicuous outliers of younger sedimentary rocks. Carboniferous Coal Measures have been preserved in the Sanquhar Basin, to the east of which, where they have been down-faulted against the more resistant Ordovician sediments, their junction gives rise to a well marked fault-line scarp. Further to the south-west, brick-red sandstones and coarse breccias of Permian age, interpenetrated by volcanic rocks and underlain by Carboniferous sediments, floor the wide embayment of the Carron Basin between Enterkin and Durisdeer, a northward projection of the wider Thornhill Basin. While these outliers of less indurated sediments have certainly facilitated the development of these lowland basins in the west and south-west, their significance, as far as the area surveyed is concerned, is limited in view of their peripheral position; the even smaller pocket of Permian breccias south of Crawford John reveals itself only on the geological map. The same is true of the numerous groups or swarms of felsite dykes with their generally Caledonian alignment, and of the less numerous but more continuous Tertiary dykes running from north-west to south-east. Of greater significance are the mineral veins, rich in lead and other ores which permeate the Ordovician strata, and although not indicated in the 1" Geological Map, attain a considerable concentration in the vicinity of Wanlockhead and Leadhills. Their exploitation in the past has been responsible not only for the establishment of these high-lying settlements, around which 'in-bye' and 'park-land' was once pushed as high as 1600' on the surrounding hills, but also for the spoliation of much of the vegetation of the hill-grazings in the immediate neighbourhood.

These minor geological details are however subordinate to the mass and extent of Lower Palaeozoic sediments. Between the Nith and the Clyde the latter form the basis of a high table-land, which sloping from over 2000' in the south-east to 1500'-1250' in the north-west, has been maturely dissected by a close net work of winding valleys into a series of irregular sinuous ridges. Only in the high Lowther ridge in the south-east, with its clearly defined alignment from north-east to south-west, is there any suggestion that geological structure has exercised an appreciable or obvious influence in the moulding of the landscape. Elsewhere, the closely spaced ridges tend rather to radiate in all directions from the centre of the area, though in the words of Geikie, that master of descriptive writing "...... even where the coincidence is more faintly marked we see everywhere a kind of striving after a north-east trend, as if the geological structure could only exercise a pervading but not very powerful influence on the process of denudation"[1].

The valleys are deeply cut, widely 'V'-shaped with narrow restricted floors and whose often meandering, but vigorously corrading rivers and burns, possess generally maturely and evenly

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1 Memoirs of the Geological Survey: Scotland (1871) p. 6.

graded courses (see F. 23). Valley sides rise by steep, smooth, convexly-curved, slopes to narrow, flat-topped or rounded, gently domed ridges, in whose general accordance of summit levels can be seen remnants of formerly more extensive plateau-like surfaces. The vertical arrangement however of these remnants suggests not one simple plateau surface with a continuous slope from 2000'-1250' but rather a more complex landscape composed of various different levels separated from each other by areas of steeper slope and each representing, what may well have been, a former base-level of erosion. Be that as it may, the nature and object of this study, together with the limited size of the area, neither warrants nor would it allow a successful detailed analysis and sub-division of possible former levels or erosion.

Suffice it to say that the composite, indeed polycylic character of the landscape, strikingly apparent in the field, is also revealed in the series of projected profiles constructed for the area (see F. 24 and F. 25) and that accordance of summit levels suggests a broad and general grouping of the remnants of surfaces of gentle slope in order of decreasing altitude at:-

1) 2000'+
2) 1900'-1750'
3) 1500'-1600')
4) 1450'-1250')
5) 1000'-750'

Further, the spatial relationships of those principal groups of summit levels (see F. 25) indicate a generally parallel succession from the highest in the south-east to the lowest in the north-west.

To the south-east the Lowther ridge trending from north-east to south-west, and with a general summit altitude of 2250', dominates the surrounding landscape, above which it rises with smooth steep curved slopes. The narrow ridge-like spurs which project from its south-east flank reveal an accordance of summit level between 1900'-1750'. The general altitude of these spurs is paralleled to the north-west of the Lowthers, where over a belt of country some one to three miles wide trending from north-east to south-west, hill summits attain a common altitude of between 1850'-1750' but where, nevertheless even more extensive areas of negligible slope occur between 1600' to 1500'. Still further to the north-west, and still parallel to the central belt, is an area of somewhat lower levels where the long spurs which separate the numerous tributaries of the Crawick - Duneaton Waters slope gently from 1500' to 1250'; here, there is a greater development and extent of gently sloping surfaces between 1250'-1450'. Finally, what the Geological Memoir[1] suggests as an erosion surface at 1000' is represented in this area by a distinct and clearly-cut bench of small gradient, and some 750' to 1000' high, between the Lower Mennock and Crawick Waters and directly east of Sanquhar (see F. 24 and F. 26). Approximately a mile and a half wide, it rises above the present valley of the Nith, while to the north-east it is terminated by a pronounced break of slope between 1000'-1500'

1 Simpson, J. B., and Ritchey, J. E., (1936) p. 2

which, in places, coincides with the fault-junction between the Coal Measure sediments and the tough Ordovician greywackes. Other indications of a surface at this height are revealed in distinct benches, again between 750'-1000', which border the Enterkin Burn and its tributaries, and also the Crawick Burn and its major tributaries - Cog Burn and Wanlock Water.

More important, however, than mere accordance of summit level is, as far as the nature and distribution of the vegetation is concerned, the altitude and actual extent of those areas whose ground surface is of small slope. Because of the high degree of dissection of the original plateau such areas are rarely very wide or continuous. The map (see F. 26) which endeavours to indicate very generally those areas where the slope of the ground in any direction does not exceed 2° makes this obvious and while, at the same time illustrating again the broad distribution of these various levels from south-east to north-west, it also revelas that the more extensive areas of gentle slope occur most commonly between 1500'-1600', and again between 1250'-1450', with more localised or restricted benches at 1750', and 1000'. While the more extensive areas of gentle slope which have been outlines are, with the exception of the 750'-1000' bench, confined to ridge summits it is characteristic of the area that the generally smooth steep slopes which bound these ridges i.e. the valley side slopes, are often composite in form also. The continuity of their smooth, steep, convex slopes are frequently interrupted by benches or flats - such as the cross sections of the Wanlock (see F. 23 (14)) the Elvan (see F. 23 (10)) and Glengonnar Waters (see F. 23 (11)) reveal, and which may represent former valley floors, but whose significance here lies rather in their effect on the vegetation of these slopes.

While, on the one hand, the component surfaces of this block of hill land decrease in altitude from south-east to north-west, the degree to which they have been dissected and the extent to which the original plateau summits survive varies quite markedly from north to south of the area. Part of the main watershed between the Nith and the Clyde strikes diagonally from north-west to south-east (see F. 27). North-eastward, drainage is directed towards the Upper Clyde which, from within a mile or two of its source, is a broad, maturely graded river meandering across a well-developed flood plain. Its basin lies at a high altitude, some 750'-1000', in comparison to that of the River Nith to the south-west. Between Sanquhar and Drumlanrig the Nith has cut its bed down to a level of between 500'-250', some 250'-500' below a former and more extensive level at 750' (part of which now forms the distinct bench already described to the east of Sanquhar). This base level some hundreds of feet below that of the Upper Clyde Valley has resulted in a deeper closer and more vigorous dissection of the south-west side of the plateau. In their upper reaches the tributaries of the Nith are still relatively youthful and headward erosion is active. The valleys such as those of the Glendyne (see F. 23 (2)), Enterkin (see F. 23 (4)) and Mennock (see F. 23 (3)) are, particularly in their upper and middle courses, deep (500'-700') relatively narrow 'V'-shaped notches with exceptionally steep slopes and with floors of limited width often restricted to that of the burn or river itself. In contrast, northward flowing tributaries as, for instance, the Elvan (see F. 23 (10)), Glengonnar (see F. 23 (11)), and Snar (see F. 23 (12)) possess more maturely and evenly graded rivers and occupy valleys which are less deeply cut (250' or less) more widely open and with less steep valley slopes and meander across narrow but nevertheless incipient flood plains, bounded, as along the Clyde to which they are graded, often by river terraces. Lebon[1], with every justification, suggests that the advantage possessed by these south-western flowing tributaries is causing a gradual regression of the main watershed northwards at the expense of the north-eastern streams, and attributes the low passes which pierce it at the head of the Crawick, Mennock and Carron Water (the Dalveen Pass) to their encroachment on the northern valleys. The watershed is certainly not a continuously high nor a clearly marked feature (see F. 27) and the development of the close network of river valleys within the area obscures it and imposes rather a radial pattern on the drainage.

Two features arising from this unequal intensity of dissection have important bearings on the development and distribution of the vegetation. First, the deeper dissection by rivers in the south and south-east of the area has contributed

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1 Lebon, J.H.G., (1935).

to a larger percentage of the land over 1000' being occupied by very steep slopes than further north - a feature which the slope analysis (see F. 28) clearly emphasises. Second, within much of the area to the south of the watershed, and again over 1000', a closer, denser net-work of valleys has reduced the original plateau surfaces to a greater number of narrower ridges than further north and the extent of areas with gentle slope is thereby considerably more restricted. This fact is not so obvious on the map of 'gentle slopes' (see F. 26), but if compared with that of the slope analysis (see F. 28) the wider extent of what may be termed intermediate slopes, 10°-2°, over the lower areas in the north-west becomes more apparent.

Only, therefore, in respect of the varying altitude of its plateau-like remnants, which provide a contrast between the south-east and the north-west of the area, and in the degree of dissection as between the south and the north, does the otherwise monotonous uniformity of landform of this high table-land exhibit any real or striking diversities which may be closely related to distinct types of vegetation. Unlike the Newton Stewart area, the Pleistocene glaciation would appear to have played here a minor role in fashioning or modifying the relief. The general ice sheets are considered to have swept from west to east across the whole area.[1] The resulting deposits (see F. 29) of 'coarse, stiff, stoney and unstratified' boulder clay (till), confined

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[1] Pringle, J., (1948) pp. 80-84.

mainly to ground below 1000', ring the area, from which fringe long tongues of material penetrate towards its centre along the valley floors, creeping up the lower slopes to 1000' and extending as high as 1250'-1500' at the valley heads. These deposits, more widespread over the lower ground to the north-west, are reduced to a very narrow fringe in the south-east. The drift map however probably tends, in indicating only the horizontal distribution of superficial deposits, to give an exaggerated impression of their importance. Even when, along the valley floors, it has been exposed by river erosion, the over burden is not of any great depth and rapidly becomes thin and patchy on the surrounding slopes, finally disappearing completely at heights over 1250'.

The smaller and more localised patches of morainic material must probably be associated with later stages of glaciation, during which there is good reason to believe that the high Lowther ridge formed a gathering ground for local valley glaciers. To their action must be attributed the ice scraped breach of the Dalveen Past, the great 'U'-shaped trough of the Carron water and the somewhat anomalous size, width, and depth of those valleys which dissect the south-east flank of the Lowthers i.e. Glenochar, Peden and Potrenick (see F. 23 (7)(8)(9)). Only in these few instances is there any evidence that the pre-glacial land forms have in any way been modified by glacial erosion. Usually obscured by a continuous cover of vegetation, and often by thick peat as well, there is little to indicate the presence of either till or morainic material on the ground or to distinguish between them, except where the latter, as at the mouths of the Leadburn and Potrenick burns forms conspicuous low moraine-like mounds. Along the margins of the wider valley floors glacial debris largely underlies ill-defined terraces of varying width and continuity.

Only along the Clyde and the Nith and the lower reaches of some of their major tributaries does alluvial material form well-defined terraces - though along the floors of most of the larger valleys dissecting the area restricted slivers of river alluvium serves to emphasise their narrowness; the continuous spread of sand and gravel bordering the Nith valley probably owes its origin to the melt water of retreating glaciers and has since been re-worked to form high terraces which provide valuable, if light and, at times, droughty agricultural soils.

Climate. While the Wanlockhead area provides a very marked contrast in landform with that of Newton Stewart, climatic differences are not so obvious nor so easy to assess. Any attempt to do so is fraught with the same difficulties and problems as in the former area. In the absence of reliable long term meteorological records for altitudes over 500', it is virtually impossible to give an accurate and satisfactory quantitative estimate of even the main climatic elements in this area, where most of the ground lies well above a 1000'. As before, information of a very variable quality is available from stations situated at low altitudes (under 1000') around, but generally without, the area actually surveyed. The Climatological Atlas of the British Isles certainly provides reliable averages for the Wanlockhead area as a whole, which have been extracted and summarised (see F. 30) but these only occasionally reflect the influence of the wide range of altitude. On the other hand there do exist a few records, regretably limited however, for Wanlockhead and Leadhills, at 1334' and 1310' respectively, by means of which the more general information may, to a certain extent, be substantiated and qualified, and a more precise impression, be it only of temperature conditions, gained for the centre of the area and for its 'middle' altitudes.

Considerably less exposed than the Newton Stewart area, being equidistant from east and west coasts and surrounded, except to the north-west, by high ground, this area has however a much greater percentage of its surface over 1000'. Having in common with the former area a heavy rainfall throughout the year, relatively high atmospheric humidity, a frequency of the hill mist and generally low summer temperatures and sunshine amount, differences as far as can be ascertained would appear to lie in its slightly longer and its certainly more severe winter conditions.

The mean annual rainfall of the Wanlockhead area (see F. 31) is heavy, varying with altitude from 50" per annum along the south-west, north-west and north-east borders to probably over

70" where altitudes exceed 2000', as on the high Lowther ridge to the south-east. Indeed, most of the area must experience at least 55"-65" a year. The general characteristics of its incidence remain the same as in the south-west - frequent throughout the year; a large number of rain days, an annual average of 225 - (minimum of 14 in June, maximum 23 December and January); 50%-60% of the annual total rain falling between October and March; a mean monthly maximum of about 8" in December and/or January and a minimum of 3.5" in May and/or June; a secondary maximum in August (6") and an additional 'dry spell' in September (4"): nor is the rainfall any less variable in amount or incidence than elsewhere.

Over this high ground, especially above 1500', with its higher rainfall, frequently low cloud and hill mist, atmospheric humidity must be relatively high, and evaporation rendered less effective by the consequently lower temperatures. As far as general averages for the whole district indicate, it does not appear to vary very drastically in this respect from that of Newton Stewart in the winter months. However, somewhat lower values for relative humidity of 65% occur in the early summer months of May-June when for the same period relative humidity is 70% in the south west.

As always it must be stressed and borne in mind that average temperatures as given by the Climatological Atlas of the British Isles must, in their reduction to sea level values, present unreal and also rather high estimates, in the case of upland country. With the average annual temperature of 47°F, the mean of the coldest month 39°F (mean minimum 31°F: mean maximum 44°F), that of the warmest 58°F (mean minimum 50°F; mean maximum 60°F) and mean average range of 19°F (mean maximum range 32°F) the Wanlockhead area differs little in respect of average temperatures from the south-west (see F. 32). Even an approximate estimation for 2000' of mean temperatures of 56°F-51°F for the warmest and of 32°F-31°F for the coldest months reveal no startling differences.

However it is in the somewhat shorter frost-free period - with average dates of 1st - 15th October, and 1st - 15th May for the first and last screen frosts respectively, in the slightly greater frequency of days with minimum temperatures below 32°F, an average of 100 per year, and in the longer average period of 20-50 days during which snow may lie during the year, that the more obvious contrasts with the south-west appear, differences which suggest the greater severity of winter conditions already mentioned. This is to a certain extent corroborated by local reports, the principal and outstanding feature of which is the emphasis continually placed on both the amount of snow and the length of its duration, accompanied often by severe drifting, especially at high altitudes and, in particular, in the vicinity of Wanlockhead.

A more precise estimation of certain climatic conditions at high altitudes can be gleaned from the temperature and rainfall records for Wanlockhead and Leadhills. It is unfortunate that records from the latter, commenced in 1914, should have been discontinued in 1927 and, that those for Wanlockhead, though covering a longer period, are for a different and earlier period, 1856-1895. In spite of these obvious disadvantages the mean annual rainfall of 69"-72" for Wanlockhead, with monthly maxima of 9"-8" in January and December and 6"-8" in August, and a minimum of 5" in June reveal the reality of the high rainfall, increasing with altitude. A study of temperature figures for both Wanlockhead and Leadhills indicate that with:-

1. mean annual temperature 43°-44°.
2. " monthly " of coldest month 33°[1] - 35°(mean minimum 30.1° and mean maximum 46.7°)
3. mean monthly temperatures of warmest month 54° approximately (mean minimum 39° and mean maximum 61°)
4. length of snow lying October - May, average of 61 days per annum.

- conditions in the heart of this area, and at the 'middle' altitude of approximately 1300', are on the average about 4° lower than the general averages given for sea level, and are very largely what might be expected given an over-all reduction of temperatures by 1° for every 300' of altitude.

Land Utilisation. Practically the whole of the Wanlockhead area lies above 1000' and the percentage of its surface between 1000'-1500', and again between 1500'-2000', is very much greater than in the Newton Stewart area. Nevertheless the amount of improved agricultural land is greater, not only in extent but also in its

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1 The lower value for Wanlockhead in comparison with Leadhills may arise from the fact that the former village lies in a hollow surrounded on all sides by high ground which may well be a 'major' frost hollow.

altitudinal range. As the vegetation map (see F. 33) indicates, the central uninterrupted mass of rough hill-grazings is all but ringed by a fringe of improved land whose width and continuity are particularly conspicuous to the north-east and to the south-west of the area.

To the north-east, the flood plains of the middle Clyde and lower Duneaton Water provide a valuable and relatively wide ribbon of low ground between 750' and 1000'. The lighter soils of the sandy terraces and river alluvium, the latter often, however, susceptible to flooding carry permanent pasture of a variable quality, with occasional fields of hay, oats, and sometimes turnips further away from the river margins. For the most part this land is used as 'in-bye' or 'downfall' by the adjacent hill sheep farms for winter feeding of hogs and sometimes of Cheviot ewes, or the summer grazing of cross-bred lambs as well as for tups, and occasionally for cattle grazing. In the region of the Duneaton-Snar Waters where valley slopes do not always rise so steeply or so abruptly as along the Clyde, enclosed park land may be carried above the 1000' contour over some of the low, gently-sloping spurs, where the spreads of boulder clay are more extensive.

To the south-west, better soils, combined with a larger area of lower ground developed across the less resistant Carboniferous and Permian sediments in the Sanquhar and Carron - Enterkin Basins, accounts not only for the wider extent of improved land but for the much higher proportion of arable cultivation that characterises it. Between 200'-250' the River Nith is bordered by alluvial haugh land and sandy terraces. Above this the broad, gently-sloping, slightly undulating, bench, so well developed between 750'-1000' east of Sanquhar and between Enterkin and Durisdeer, has allowed a wider development of improved and arable land. In spite of poor drainage conditions, particularly on the Coal Measures where patches of unimproved moss still remain, a relatively high altitude and the difficulty of access occasioned by the steep slopes surrounding these bench lands and by the often poor and inadequate roads, the proportions of arable cultivation is remarkably high, especially on those dairy farms which, more common to lower Nith valley itself, are situated on the outer margin of the bench. Towards its inner margin it provides those adjacent hill-sheep farms with a higher proportion of improved land than is normally found within the more central and northerly parts of the Wanlockhead hill area. As a result they carry a higher acreage of arable cultivation than in the pure hill-sheep farms, and greater variety of stock, Cheviot ewes, cross-bred lambs, Galloway cattle, summered on the adjacent hill and, in one or two cases, a small herd of dairy cows.

Over most of this area however, where altitudes exceed 1000' slopes are frequently steep, soil and climatic conditions harsh, the breeding of black face sheep is ubiquitous. The hill farms are generally large - 2000-3000 acres, but with a wide range of size from 9000 acres to 500 acres. Summer stocking varies from 3 acres per ewe in the east to 1-2 acres per ewe in the south and south-east and, with the large amount of 'white' land, the small amount of in-bye and severe winter conditions, many of the hogs are wintered away in lowland farms in Ayrshire and Lanarkshire.

Within the main mass of the rough grazings the minute and scattered patches of improved land, varying in altitude and situation, represent a few acres of in-bye around the shepherds' houses and the smaller sheep farms. There are indications, within and around both Wanlockhead (see F. 63 (23)) and Leadhills, that cultivations in the form of 'parks' or 'gardens', now abandoned, were at one time, when lead mining was active, pushed up the surrounding hills as high as 1500' or 1600'. For the most part, however, the present limit of arable cultivation rarely exceeds 750' though enclosed improved grassland, while reaching an average limit of 1000', does in certain instances extend as high as 1250'. Above this limit bald, treeless, moorland persists everywhere. Remnants of what may be natural or semi-natural deciduous woodland survive, as scrubby and, often open, patches of oak and birch together with frequent hawthorns and rowan, only along the steep banks where the Lower Crawick, Mennock and Enterkin burns have incised their courses deeply into the 750' bench.

CHAPTER VII

Vegetation of the Wanlockhead Area - Dry Moorland

Dry Moorland. The vivid contrast between the gnarled, rugged, disordered topography of the Newton Stewart area and the smoothly flowing curves and simplicity of form of the more massive table-land of Wanlockhead is reflected in a parallel, if less obvious contrast in their vegetation covers - a contrast revealed primarily in the very much greater extent of dry moorland, and in particular, of that dominated by Calluna vulgaris, in the latter area. The pattern of associations (see F. 33) is no less diverse or complex but at least, the continuity of unbroken, smooth and often steep slopes alternating with flat-topped ridges, between which the change in gradient is often sharp, has resulted in a greater ease of distinction between wet and dry moorland.

Considering first, the associations of the dry moorland type, it is well to remember that, while they are fundamentally similar to those outlined for the Newton Stewart area, there are often considerable differences in their extent and distribution and, at times, their specific composition may reveal slight variations.

Summit Vegetation. As in the south-west, the summit vegetation is primarily a grass-dominated association which is distinguished from the more widespread dry grass moorland, into which it usually grades at lower altitudes, by its shorter growth and sward-like appearance, the paucity of its species, and a greater abundance and proportion of Vaccinium myrtillus and Galium saxatile than is found in any other association. Its composition varies very little, a characteristic sample revealing:-

Festuca ovina	(with some F. ovina var. vivipara)	(co-d)
Vaccinium myrtillus		(co-d)
Galium saxatile	(a)	
Polytrichum commune	(f)	
Cladonia spp.	(f)	

with here and there wide patches of Luzula sylvatica, the whole growing on a thin layer of peaty soil.

This association is confined to the Lowther ridge (see also F. 24) in the south-east of the area, since only here do altitudes exceed 2000'. It forms a conspicuous and continuous cap over the summit of the ridge from Green Lowther (2403')[1] to Lowther Hill (2377')[2] above, it should be stressed, approximately, and at least, 2250'. Rarely does it extend below this altitude and even over those other culminating points of this ridge which attain but do not exceed 2000', it is usually absent or of such feeble development and of such limited extent that it could hardly warrant a place on the vegetation map.

Certainly it is related by its specific content to the dry grass moorland into which it merges at lower altitudes, and with which it shares most of its species in common. But the dry grass moorland is neither so limited in its distribution nor is it confined to such a definite habitat.

Dry grass moorland. This again is very similar to its counterpart in the south-western area both in composition and general habitat

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1 Map reference /900120.

2 Map reference /890107.

conditions. The grass species of which it is composed are various, usually mixed, and include:-

Anthoxanthum odoratum	(a)	often (d)
Nardus stricta	(f)	:occasionally (d) though as such it is inclined to be patchy and not particularly concentrated in its distribution.
Festuca spp.	(a)	usually fine-leaved.
Agrostis spp.	(a)	
Aira flexuosa	(o-f)	

of which, A. odoratum, as far as could be ascertained, would appear to be most frequently dominant. Certainly, it is a more abundant and more frequent member of the association than in the Newton Stewart area. These grasses which in many instances grow to such a length, often a foot or more in height, as to give the grassland an almost 'meadow like' appearance (see F. 62 (16)), are accompanied by the usual and more common moorland plants:-

Galium saxatile	(a)	especially in ground layer
Potentilla erecta	(f)	
Vaccinium myrtillus	(o)	though often abundant on very steep, dry, unstable slopes.
Calluna vulgaris	(o-a)	varies considerably in amount, increasing usually towards the margins of the grassland association.
Molinia caerulea	(v. o.)	more usual at low altitudes, below 1500'.
Empetrum nigrum	(v. o.)	
Rumex acetosella	(o)	
Luzula sylvatica	(f)	occurring in wide dense patches.
Polytrichum commune	(o-a)	varies in amount but at times may be very abundant indeed in ground layer.
Hypnum scheberi	(o)	

the whole growing in a well drained, usually dry, peaty soil of greater depth, though seldom exceeding 6", and of a more fibrous nature than in the former association. In some instances, especially on very steep slopes, this peaty layer is so extremely thin and dry as to make it difficult to differentiate it clearly from the underlying mineral soil - friable, coarse, stoney - whose angular fragments can often be seen projecting through the grass cover.

As such, dry grass moorland occurs in varying amounts throughout the length and breadth of the Wanlockhead area from 750' up to its limit at approximately 2000'-2250', but attains its finest development on those steep smooth slopes whose gradient usually exceeds 10^{o} (1:6), and in many instances 20^{o}, and its most conspicuous and continuous extent where such slopes occur at higher altitudes. This distribution is most striking on the Lowther ridge whose smooth steep grass covered slopes dominate the surrounding moorlands above 1750', on its north-west, and above 2000', on its south-east, flanks, and which carry practically unbroken grassland from 750' or 1000' to 2000' on the more youthfully dissected and exceptionally steep slopes of its south-western and, to a lesser degree, over its north-eastern end, (see F. 62(17): F. 66(35): F. 67(36)). A similar habitat, but much smaller area, is provided by Stood Hill (1925')[1] whose grass-covered slopes and summit stand in marked contrast to the dark heather-covered moorlands above which it also rises (see F. 65(33)). In both instances, the grass moorland covers slopes and summits below 2250' alike, with its continuity interrupted only in the latter position by discontinuous patches of 'mossy ground'.

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1 Map reference /857126.

Elsewhere this association occurs frequently throughout the area, often in wide stretches but usually in more localised patches on the steep valley side slopes which habitat it shares with, and in which it either interpenetrates or alternates with, dry heather moorland and bracken.

In its composition it is remarkably constant with but slight variations related in some cases to physical conditions, in others to human factors. On the less steeply inclined slopes and spurs it is most luxuriant in its grass species and its height of growth, and Anthoxanthum odoratum is most obviously dominant, with often abundant mosses, especially Polytrichum commune in the ground layer. Where the gradient is very steep (20°-30°) it is frequently short, closely cropped, the superficial peaty layer of the soil is thin and dry, and Vaccinium myrtillus often abundant, if not at times dominant. Such slopes are frequently gashed by deep gullies, not only where headward erosion is active at stream sources, but over excessively steep slopes where the stability and equilibrium of the vegetation cover and the thin skeletal soils has been progressively disturbed by over-burning, grazing, and particularly sheep-treading. Under certain circumstances every stage in the inexorable destruction of the vegetation and consequent savage slope erosion can be seen and, as the photographs (see F. 62 (18), (19), (20)) illustrate, three stages in slope destruction can be traced from; steep slopes ringed by the numerous 'terracettes' which have arisen no doubt as a result of accelerated soil creep occasioned by a degeneration of the vegetation cover and the continual progression of sheep around the contours of the hill; the development of more pronounced and continuous sheep tracks from which wide sheep scars have stripped whole blocks of vegetation on their down-slope sides; finally, such denuded patches, potential danger spots, provide the starting point for gullying and slumping downslope brought about by the concentrated and rapid run-off of rain water particularly during heavy and intense downpours. Once initiated, such gulleys, taking every advantage of minor irregularities of the slope, tend to concentrate run-off more and more, and to extend uphill by headward erosion, devasting wide areas of these steep dry grass slopes.

Within this dry grassland, Nardus stricta is ubiquitous but never so abundant nor so frequently dominant as, for instance, further east. Here and there its conspicuous tufts whiten the grassland, but only on the south-east flanks of the Lowthers, where remnants of thick peat hags still cap the flat-topped spurs, does it really come into its own, although even under these circumstances, it is hardly widespread or dominant enough to justify its recognition as a separate association. Calluna vulgaris also occurs frequently and in varying amounts throughout - sometimes small and scattered, in other instances in compact isolated clumps or hummocks, indeed, often so prevalent that only the somewhat greater amount of grass taken over a whole area justifies its being mapped as such.

It is reasonable to assume, as before, that this association represents a sub-seral stage to the purer dry heather moorland - with which association it is frequently mixed and with which it shares a similar habitat. And, given favourable habitat conditions of steep, well drained slopes, it owes its dominance largely to such biotic factors as heavy burning and grazing rather than to purely physical factors alone. The sharp and striking boundary between dry heather and grassland (which often occurs on either side of a dyke or on opposite sides of a valley), as well as surviving remnants of heather in one form or another within this association, certainly testify to this. The peculiar dominance of a grassland in which neither heather nor Nardus play a conspicuous part, over most of the Lowther ridge, and to a much smaller extent on Stood Hill, must further be correlated with, not only the excessively steep slopes but also with the narrow, restricted, and considerably exposed nature of the summit ridge. The limited area of the summit may either have hindered the development of thick peat or have facilitated the rapid removal of such a peat cap if it did in fact ever exist there. Such conditions, where erosion on the steep slopes has limited or destroyed the peat layer and where there is little or no down-wash of acid peat eroded from above, may as Fenton[1] pertinently observes, be "less favourable to heather or Nardus and more favourable to grasses", and in this instance account for the predominance of 'white land' on the Lowther ridge.

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[1] Fenton, E.W, (1953) p. 152.

Whatever the cause, or complex of causes, there can be little doubt that dry grass moorland in its various forms is intimately related to Dry heather moorland[1]: This is the 'black hill or land', dominated by Calluna vulgaris and most usually, and commonly, linked in the sheep farmer's mind with 'hard ground'. An often ambiguously used term, it is one which nevertheless aptly describes the soil conditions over which this association most frequently grows - a thin layer of peat or peaty soil, dry and markedly fibrous, seldom exceeding 6" in depth, and often considerably less, on a coarse substratum, varying in depth, and composed of angular fragments of weathered Ordovician bed rock. Conditions for the development of dry heather moorland would appear to be, as in the former association, slopes steep enough to give adequate drainage combined with regular, but not too intensive, burning or grazing. Throughout the Wanlockhead area, dry heather moorland is prevalent from 750'-2000' on all steep slopes, especially those of the more sheltered and often considerably shaded, deeply cut valleys. While, however, characterised by a dominance of Calluna vulgaris on a thin well-drained peaty soil, its composition reveals slight variations dependent upon differences of management or site.

In its purest and finest development it is essentially a closed community, dominated often to the exclusion of all other species by short (ankle deep) healthy Calluna vulgaris (see F. 63 (21)). As such, and representing the results of well-managed

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1 'Calluna - Heath' Community of Anderson, M. L., (1950) p. 39, of Tansley, A. G., (1949a) pp. 743-772.

grazing and rotational burning, it is comparatively rare and limited in extent. For the most part the heather dominated areas present an irregular patchwork of vegetation, resulting from a more haphazard method of burning, across which heather plants of every age and of every combination from pure heather to practically pure grass are revealed. In some cases the heather plants are long (over 1') leggy, open, and with a number of associated moorland plants in the ground layer, the commonest being:-

Galium saxatile	(f)
Potentilla erecta	(f)
Vaccinium myrtillus	(o-f)
Nardus stricta	(f)
Aira flexuosa	(a)
Anthoxanthum odoratum	(f)
Agrostis spp.	(f)
Polygala vulgaris	(o)

Mosses, particularly Polytrichum commune.

More frequently, in other instances, severe burning of small patches has resulted in the establishment of a mixed vegetation establishing itself among the dead, whitened, branches of the former heather growth. Calluna, usually small and scattered may or may not be dominant - grasses occupy a greater space, particularly Aira flexuosa (which may be completely dominant after a recent burn) (see F. 63 (21)), Nardus stricta, Anthoxanthum odoratum and Agrostis spp.

Where slope conditions render drainage less effective and rapid, or where the downward wash of acid peat is pronounced, various wet moorland species become conspicuous and the association grades into wet moorland of one kind or another. In some cases pure heather may be found on deeper (over 6"), wetter, and more amorphous peat - a condition which often arises from either the drainage or erosion of 'mossland' - although, in most instances it is advisable, as has been done here[1], to distinguish between this 'deep ground' and the 'hard land' of the typical heather moorland. Conversely on very steep (over 20°) and often south facing slopes, where, no doubt, as a result of injudicious burning, rapid erosion and wastage of peat has been initiated with, in places, an exposure of the underlying mineral soil or, in extreme cases, considerable instability of slope and heavy screeing - Calluna vulgaris may be replaced by Erica cinerea and, to a lesser extent, by Vaccinium myrtillus. This is particularly striking on some of the very steep, south facing, slopes of the Mennock valley - where much of the lower slopes still remain devoid of vegetation (see F. 63 (22)).

Considering then the Wanlockhead area as a whole, in so far as they possess similar requirements of physical, and in particular landform, habitat, the distribution and occurrence of dry heather and dry grass moorland are similar - particularly favoured by both are those steep slopes in the more deeply and closely dissected parts of the area (see F. 63 (24) and F. 66 (34). On balance, however, there is rather more 'white' than 'black' land, but given suitable physical conditions the dominance of one or another in any particular locality is largely determined by biotic, or a more complex combination of biotic and physical, factors. The most continuous extent of dry heather moorland

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1 See page 143 for further consideration.

occurs over a wide belt of land aligned north-east to south-west across the centre of the area (Wanlockhead and Leadhills are approximately in the centre of this belt), within which the general altitude is between 1750'-1800' (see F. 24 and 25). Whether this distribution is due to management or 'site', or indeed is significant at all, would be well-nigh impossible to assess without a more detailed appreciation of the history of the land utilisation of the area. It may be related to the fact that within this area occur some of the deepest valleys and steepest slopes (outside the Lowther ridge) - the latter often shaded for long periods of the day even in high summer. In some cases heather is more prominent on north facing slopes but the converse is so often true, or there is no appreciable difference, that no generalisation of the effect or significance of aspect[1] could be vouchsafed in an area as small as this. It is, however, worth noting that one of the largest unbroken areas of well developed dry heather moorland occurs over that block of moor directly north of Leadhills, on steep slopes associated with the pronounced dissection by the right hand tributaries of Glengonnar water (see F. 66 (34)). This is a case of moorland carefully managed, regularly and systematically burnt in small

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1 Fenton, E.W. , (1951a) p. 41 discusses this problem. While it is obvious that in the same valley with slopes of equal angle on both sides, the fact that the sheltered, and the north-facing, shaded, slopes usually moister and containing more mosses retard the rapid wastage of peat, management and in particular burning determines the nature of the dry moorland vegetation and the quantitu and quality of the heather content. It is reasonable to expect, however, under certain circumstances, that intensive and continued burning might well obscure the natural advantages offered by aspect to the preservation of a peaty layer and a heather cover.

patches for grouse as much (if not more) as for sheep feeding. Elsewhere, however, farmers and shepherds are less precise about the extent and regularity of heather burning. A rotation of 7-10 years is recommended for the Wanlockhead area as a whole - preferably in wide patches; but, the vagaries of weather and the ubiquitous problem of labour shortage would appear to confine such a rotation to the realms of theory rather than practise - also, with a high proportion of 'white land' over much of the area, less emphasis is given to the problem of heather burning than in other parts of Southern Scotland.

Over much of the ground occupied by steep slopes - despite the wide and noticeable covers of either pure heather or pure grass there is a considerable inter-mixture of the two. The form of the mixture may vary widely from - small heather scattered evenly through a mixed grass vegetation: alternating patches of varying size of well developed heather and grass: isolated though conspicuously rounded cushion-like clumps of heather[1] within areas otherwise dominated by grass. The balance in most cases would appear to be in the favour of grassland particularly, it should be stressed, on those very steep slopes where erosion is an active and important factor. Where the proportions were such as to make a clear distinction between a grass or heather association difficult, the vegetation is indicated as far as possible by the <u>mixed heather and grass moorland</u> association. Outside the area of the high Lowther

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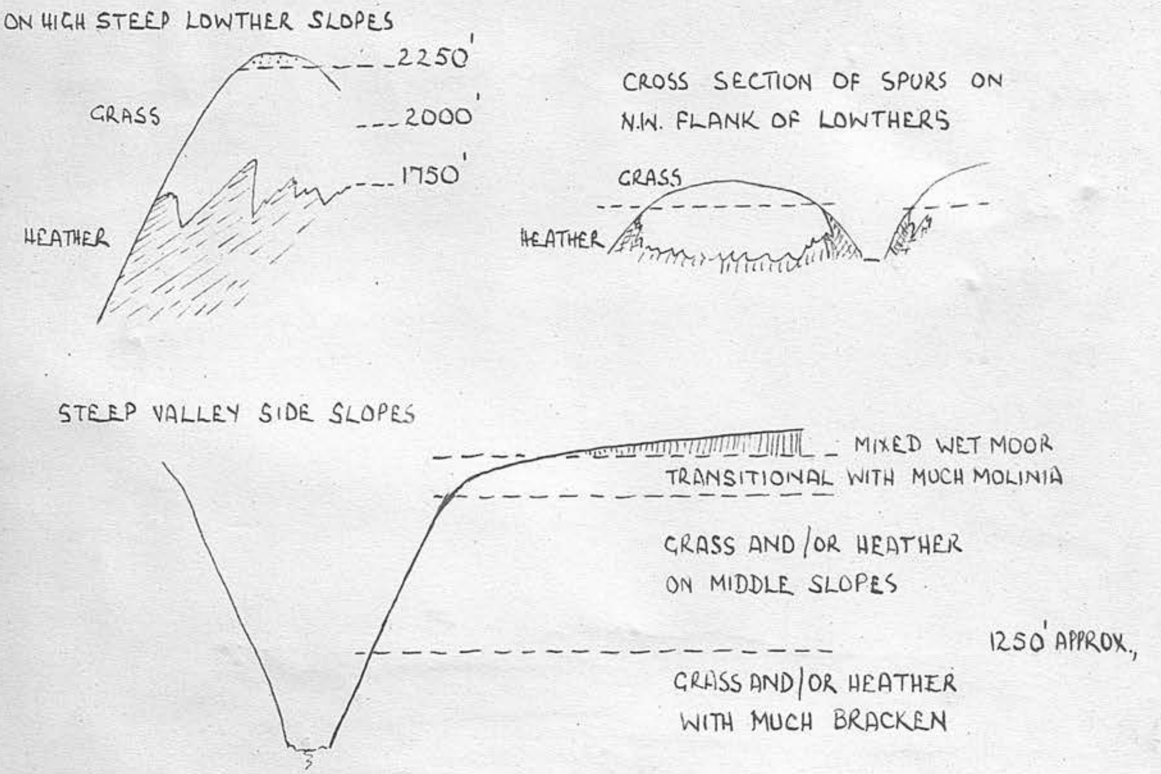
1 Fenton, E.W., (1952) p.66 indicates that this condition arises when heather is dying out.

DIAGRAM 3.

DIAGRAMMATIC REPRESENTATION OF SOME OF THE RELATIONSHIPS BETWEEN DRY GRASS AND/OR DRY HEATHER MOOR



ridge, heather and/or grass, and/or a mixture of the two, are best developed on steep slopes - and in particular the middle slopes, above which the association is modified by the influence of wet moorland, below which it has so often been invaded and replaced by bracken. Some of these relationships between the various associations discussed in relation to 'slope' have been very simply illustrated in Diagram 3 (opposite).

CHAPTER VIII

Vegetation of the Wanlockhead Area (contd.) - Wet Moorland

Wet Moorland and Intermediate Associations. In contrast to the steep well-drained slopes, the flat or gently inclined surfaces where slope is, or was at one time under given conditions of rainfall, insufficient for adequate drainage, compose the second type of landform or physical 'site'. To a marked degree these are fairly clear-cut units associated usually with the summits of the many ridges into which the area has been carved. But, although numerous, the mature and close dissection of the relief has limited their extent to long, often narrow, and essentially discontinuous areas, as is illustrated by the slope analyses (see F. 26 and F. 28). The former map reveals that in actual fact, the amount of almost flat or very gently inclined land (less than 2^{o}) is small, although a comparison with the latter map indicates a much wider extent of what, for convenience may be called intermediate slopes (10^{o}-2^{o}). Apart from the well-developed erosion surface east of Sanquhar, and the flat or gently inclined river terraces, it is the ridge summits which form the focal points, the loci, for the development and distribution of wet moorland.

As in the Newton Stewart area wet moorland is here distinguished by an assemblage of typical wet moorland plants, growing on an appreciable depth of peat, often wet and usually amorphous in its lower layers at least. Within the Wanlockhead area this community can be broadly sub-divided into four major associations, each characterised by -

(1). the dominance of one or more typical wet species.
(2). a distinctive form or appearance - more usually a characteristic colour.
(3). a general altitudinal relationship to one another.

In order of descending altitude they are:-

Association	Dominant Species	Colour	Range of Altitude of Optimum Development.
1. Hagged peat with heather.	Calluna vulgaris, with Rubus chamaemorus characteristic.	'black'	1750'-1900' (occasionally 1500'-1750')
2. Mixed Wet Moor	(Calluna vulgaris (Scirpus caespitosus (Eriophorum vaginatum	'brown'	1500'-1700'
3. Eriophorum Moor.	Eriophorum vaginatum (usually strongly tufted)	'green'	1250'-1400'
4. Molinia Moor	Molinia caerulea	'dark purplish-green'	750'-1250'

Of these, Hagged peat with heather usually dominant, forms conspicuous, if somewhat local and small, patches of vegetation capping some of the higher summits and ridges. The predominance of Calluna vulgaris, often to the exclusion of all other species, makes its classification as a member of the wet moorland group debateable. But, even in the absence or paucity of other wet species, the depth of soft peat which forms its basis distinguishes this association, sometimes termed 'heather moss' or 'fat' 'deep' or 'soft' land, for the farmer at least, from the essentially 'hard' ground of the dry heather moorland.

The peat layer is usually over 2' deep, seldom less than 1' but rarely in this area exceeding 4', is soft fibrous in its upper, amorphous and crumbly in its lower layers and has in most instances been undergoing severe erosion and dissection. This has resulted in originally continuous blocks of peat being dissected and broken up by numerous channels or cracks (hags) which have reduced the peat cover to a number of ridges and mounds. The black edges of the eroded peat serve to outline such areas very distinctly and to justify, apart from other factors, their individual recognition. On these hagged areas the higher proportion of Calluna vulgaris than is normally associated with the other wet moorland associations tends to accentuate the dark, almost 'black' appearance of the whole association when viewed from a distance.

The vegetation of these areas varies according to the areal extent of the peat layer and the degree to which it has undergone erosion and consequent desiccation. The following assemblage of plants is characteristic, with one or another playing a larger part under particular local conditions:-

Calluna vulgaris	(d)	usually dominant and particularly abundant on the smaller patches of peat or around the edges of the larger: Often 12"-18" high, leggy, woody and generally open and accompanied by such other species as -
Vaccinium myrtillus	(a)	sometimes (co-d) especially where drainage has been more effective, and peat is dry.
Empetrum nigrum	(f)	

Eriophorum vaginatum Eriophorum angustifolium		both (f) though they vary in amount in some instances Eriophorum angustifolium only occurs and may be co-dominant with heather - it is more abundant in this association than elsewhere.
Scirpus caespitosus	(f)	gaining dominance over Eriophorum especially towards the centre of peat areas.
Erica tetralix	(o-f)	
Rubus chamaemorus	(o-a)	generally present and often abundant it can, whatever its quantity, be considered <u>characteristic</u> of this association: rarely and indeed never to writer's knowledge found without the areas shown as hagged peat on the vegetation map.
Sphagnum spp. (f) - (a)		varies very considerably in quantity; on drier areas absent or discontinuous though on others heather with Rubus chamaemorus were found growing on a practically continuous ground layer of red sphagnum.

This association, whose separate classification on the basis of vegetation alone might well be considered arbitrary, has however, in most cases, as well as a definite form and colour, a characteristic position and distribution, in relation to the other wet moorland associations. It is most strikingly developed on the conspicuously flat-topped spurs of the south-east flank of the Lowther ridge (see F. 24b). Here, distinctive patches of severely hagged peat occur between 1750'-1900' and stand in sharp contrast with the dry, and often grassy, moorland on the steep slopes both above and below them (see F. 63 (25) and F. 66 (35)). To the north-west of the Lowthers fragments are found at somewhat lower altitudes of between 1750'-1500' but, nevertheless, still on the higher parts of the ridges and spurs within this central part of the area (see F. 24b). Here, however, it is not so definitely outlined as in the former locality and since it often grades imperceptibly into either the specifically closely related, mixed wet moorland at lower altitudes or dry heather moorland on the steeper bounding slopes, it is less clearly distinguishable from the surrounding vegetation. Also hagging is not so pronounced and the Sphagnum layer more continuous - but heather still predominates (a dominance due here probably more to burning than to advanced desiccation), while the presence of Rubus chamaemorus[1], plus the fact that there is a general tendency for large blocks of the peat and its associated vegetations to slump down adjacent steeper slopes, (see F. 63(26)) may be regarded as indicative that erosion, possibly subterranean, is not entirely inactive.

Except in the case of the high south-eastern spurs this hagged peat vegetation, which might well be alternatively designated 'heather-moss', merges into mixed wet moor at lower altitudes, and often, especially where burning has increased the proportion of heather, the transition to a more widespread, a more variable, mixed, type of wet moorland may at times be abrupt and clear.

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1 Fenton, E.W., (1952) p. 70 notes the occurrence of this species in a similar association, and its frequent presence in places where either surface or subterranean erosion is in progress, tempts him to regard it as an erosion-indicator. The present writer's observations would certainly seem to corroborate this correlation - also stated again in, Fenton, E.W., (1953) p. 152.

<u>Mixed wet moorland.</u> It should, at the outset, be stressed that this association bears but little relation to, and can only to a superficial degree be compared with, the mixed wet moor association of the Newton Stewart district. In that area it is fundamentally a composite association, comprised not only of two or more co-dominant species, but of two or more distinct associations. However, in order to avoid a multiplicity of terms, and also for the want of a more adequate one, this essentially descriptive title is used again in the Wanlockhead area for an association which owes its classification primarily to its plant (i.e. specific), albeit very varied, content.

In contrast to the immediately preceding association, mixed wet moor is more widely developed, it appears to occur under wetter and on the whole less adequately drained conditions, and it is composed of a greater number and variety of species. In its most typical composition it is dominated by three species - Calluna vulgaris, Scirpus caespitosus, Eriophorum vaginatum - in an equal and diffuse mixture and accompanied by a variety of other wet moorland plants... the whole being characteristically, in summer, a 'brownish' colour. Generally of a short growth, though occasionally tufted, it normally occurs on soft, wet peat of at least 9", and usually more, in depth.

The proportion of the three co-dominants may vary from one locality to another. Calluna vulgaris is invariably present - indeed its presence serves to distinguish this association from the closely related Eriophorum moor - and is usually short and fairly evenly distributed throughout the vegetation. The relative proportions, however, of both Eriophorum vaginatum and Scirpus caespitosus vary. The latter is perhaps most frequently present although, in some instances, either Eriophorum or Scirpus <u>alone</u> may be co-dominant with Calluna. Similarly, they too are short and scattered, though both species may at times be strongly tufted and form large tussocks; this habit, however, is not commonly characteristic of the association as a whole.

These three co-dominants are accompanied by:-

Eriophorum angustifolium	(o.-l. f.)	though rarely as abundant as in well-hagged peat.
Erica tetralix	(f.-a.)	
Molinia caerulea	(f.)	is <u>always</u> present; usually short, non-tufted and very diffusely scattered; it varies very considerably in amount becoming more noticeably abundant towards the outer margins of the association. Though never attaining real dominance, it can be considered as <u>characteristic</u>.
Sphagnum spp.	(f-a)	also varies in amount; over many square yards it may form a continuous ground layer but more usually its distribution is patchy and discontinuous.

A varient of this diffuse, evenly mixed, type of vegetation is that in which all the species already named are present in the proportion indicated, but in which Eriophorum vaginatum forms well developed tussocks in a carpet of Scirpus caespitosus, Calluna vulgaris, Molinia caerulea, Sphagnum spp. In this form the vegetation is however more closely related to Eriophorum moor and indeed marks a transition towards it - only the somewhat higher proportion of Calluna serving to identify such patches with the mixed wet moor. Under drier conditions, especially where the Sphagnum layer is absent, the wet species are accompanied by such drier representatives as Empetrum nigrum, Vaccinium myrtillus, Nardus stricta, Anthoxanthum odoratum, Aira flexuosa, Agrostis spp., Potentilla erecta and Galium saxatile. These drier mixtures occur at random throughout the association and appear to be closely related, if not arising directly from, the results of severe burning, indicated by the presence of the whitened remains of dead heather stems.

This mixed and very variable association must be considered as belonging to what Pearsall describes as that "very diverse series of 'mixed moors', marked by varying proportions of the larger plants, by the absence of a continuous Sphagnum cover and by a decreasing proportion of the characteristic but small bog species".[1] Initiated as 'blanket' bog under conditions of high rainfall on areas of small slope, it is probably a derivative of a purer and wetter type of bog-vegetation, and owes its present mixed character to its utilisation and modification by man and his animals. It is certainly subjected to constant sheep grazing, being particularly valuable because of the variety of herbage it offers and with such species as Eriophorum, Scirpus, and Molinia providing a valuable bite in early spring; and also, by its wetter nature, it offers alternative grazing areas in droughty summers when many of the steep grass, and to a lesser extent

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[1] Pearsall, W.H., (1950) pp. 150 et seq.

heather, covered slopes become dry and burnt-up. Much of the ground covered by mixed wet moor has at one time or another been drained - and where such artificial drainage is still effective the larger plants especially heather are more abundant, tussock development is not uncommon, and the Sphagnum layer is discontinuous. Peat cutting over this relatively low and accessible association has further modified the original vegetation. Not only has this activity, much greater in the past than at present, reduced the depth of the peat layer over wide areas, but it has affected the natural drainage - in some instances increasing its effectiveness in others, especially where cutting has resulted in enclosed depressions, allowing water to stagnate and a thick, and at times, almost pure Sphagnum cover to establish itself. In the Wanlockhead area, however, as far as can be assessed, burning seems to have been, and still remains, the most effective modifying agent responsible for the high proportion of heather and in places for the complete destruction of the Sphagnum layer.

In this diverse and extremely modified condition the mixed wet moor association occurs in varying amounts throughout the area from about 1000'-1250' up to, though rarely exceeding, 1700'-1750'. It is most widely developed on those flat or gently inclined surfaces at what might be called 'middle-altitudes' of 1500'-1700'. Considering the area as a whole, the vegetation map (see F. 33) reveals a well marked concentration across that belt of the country, which with the villages of Wanlockhead and

Leadhills at its centre, is aligned from north-east to south-west, an area already distinguished by its general accordance of summit altitudes[1] (see F.24 and F.25). Within this locality are some of the most extensive areas of gently sloping ground between 1500'-1700', and, in particular, it is here that the development of almost flat topped ridges and spurs is most strikingly seen in such as Bulmer Moss,[2] Dun Moss,[3] Harryburn Brae,[4] to the north-east of Leadhills, and Meikle Snout[5] and Middle Moor[6] to the south of Wanlockhead. To a lesser extent, mixed wet moor is also developed at about 1500' on the higher parts of those long gently convex spurs which, to the north-west of this central belt, extend from south-east to north-west. (See F.24:F.25 and F.64 (30)). Here, in particular, the spatial relationship of the association to that of the preceeding hagged peat appears to be very similar to that observed by Fenton in other parts of south-east Scotland where, he says, "at higher levels erosion has left certain surface parts drier, Cotton Grass (Eriophorum vaginatum) Heather (Calluna vulgaris) Crowberry (Empetrum nigrum) and Cloudberry (Rubus chamaemorus) are often associates, with some Sphagnum present. At lower levels where there is little or no run-off and where drainage is impeded, Cotton Grass is often locally dominant and is often associated with Deer Grass (Scirpus caespitosus) Molinia

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1 See page 115

2 Map reference /900175.

3 Map reference /917182.

4 Map reference /928186.

5 Map reference /845099.

6 Map reference /858108.

(Molinia caerulea) Cross Leaved Heath (Erica tetralix) and occasionally Bog Asphodel (Narthecium ossifragum). Under drier conditions Heather, Blaeberry (Vaccinium myrtillus) and Crowberry are commonly found".[1]

At even lower levels, and often on the same ridge or spur, the mixed wet moor undergoes a further modification revealed in a very considerable decrease in the quantity and size of Calluna vulgaris amounting sometimes to its virtual disappearance, a marked dominance of Eriophorum vaginatum with a strongly developed tussocky habit and a consequent change in colour from a 'brown' to a 'green' moor. On the basis of these principal characteristics it has been considered reasonable to distinguish and represent as a separate association:-

Eriophorum moor. There is little doubt, however, that it is closely related to the mixed wet moor with which it shares most of its species in common, although in somewhat different proportions, and it is likewise normally associated with an appreciable depth of peat. Also, while its, at times excessively, clumped or tussocky habit and the dominance of Eriophorum are its principal identificatory marks both the composition of the tussocks (often 6"-12" high) and the associated vegetation of the ground layer show certain variations, as the following samples indicate:-

(1) Eriophorum vaginatum (d) large practically pure tussocks.

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1 Fenton, E. W., (1952) p. 78.

(in ground layer between tussocks)

Scirpus caespitosus	(f)	
Sphagnum spp.,	(f-a)	
Erica tetralix	(f)	
Calluna vulgaris	(f)	but always small and relatively inconspicuous.
Vaccinium myrtillus	(o)	

(2)	Eriophorum vaginatum	(d)	in large tussocks of matted vegetation associated with Scirpus, Erica tetralix and Sphagnum between the clumps.
	Empetrum nigrum	(f)	
	Eriophorum angustifolium	(o)	
	Vaccinium myrtillus	(o)	
	Calluna vulgaris	(o)	

(3)	Eriophorum vaginatum	(d)		in matted tussocks.
	Scirpus caespitosus	(f)		
	Aira flexuosa	(f)		
	Vaccinium myrtillus	(f)		
	with			
	Polytrichum commune	(a)		occupying ground layer between clumps.
	Sphagnum spp.	(f)	but not continuous.	
	Calluna vulgaris	(f)	but very small.	

(4)	Eriophorum vaginatum	(d)	strongly tufted.
	Aira flexuosa	(f)	
	with		
	Polytrichum commune	(a)	occupying ground layer between clumps.
	Vaccinium myrtillus	(f)	
	Sphagnum spp.	(o-f)	
	Calluna vulgaris	(f)	

A less tufted variety, in which less well defined 'clusters' contain Eriophorum vaginatum, Aira flexuosa, Scirpus caespitosus, Sphagnum and a considerable quantity of Polytrichum commune are associated with spare Calluna vulgaris, Vaccinium myrtillus and Erica tetralix, also occurs. Such variations must depend on local variations of slope, drainage and management. They suffice however to illustrate the gradual gradation from very wet Eriophorum moor (1) and (2) with an almost continuous Sphagnum layer and closely related to the mixed wet moor which it so often adjoins, to drier conditions at lower levels (3) and (4) where the number and amount of wet species is smaller, Polytrichum commune occupies a prominent position in the association and the tussocks are usually more widely spaced.

Eriophorum as an individual plant is prevalent throughout the area in all types of wet moor; Eriophorum moor, in varying amounts, clothes areas of gentle slope from 1250' (and sometimes from 1000') to 1500'. It does not, however, occupy as large a proportion of ground surface as mixed wet moor and while on occasion interspersed or alternating with this latter association, Eriophorum moor would appear, as far as could be deduced from the Wanlockhead area, to occupy a position generally perpheral to it at lower levels and to attain its optimum development at about 1250'-1400'. The largest areas of Eriophorum moor occupying such a position and relationship to mixed wet moor occur in that north-western belt of country where long flat topped or gently domed spurs slope gently from 1500'+ in the south-east to 1250' in the north-west (see F. 24 and F. 25).

In all instances Eriophorum moor is so closely related to, and so obviously derived from, the preceeding mixed wet association that there would be every justification for grouping the two together for representation on the vegetation map. The exact relationship however and the actual means by which it has been derived are problems to which no satisfactory or conclusive answer can be given. Nevertheless, it can be safely assumed that either more intensive burning and/or differential grazing at the comparatively lower levels at which the association occurs

<u>may</u> be responsible for the poor development or absence of Calluna vulgaris. As the aerial photographs indicate (see F. 68 (37)), mixed wet moor often passes into Eriophorum moor by a fairly sharp vegetation change - a well marked change of colour along a definite line clearly suggesting burning as one of the dominant factors. The tussock development suggests no ready or easy explanation. Much has been written about this habit, but the reasons given for its development are often somewhat divergent. Fenton[1] for instance, states that Eriophorum is frequently tufted in natural growth - a habit he suggests due largely to a plentiful flow of water over the peat surface. On the other hand, both Pearsall[2] and Thomas[3] maintain that conditions of artificial or increased natural drainage induce the development of a tussocky habit.

Pearsall also proceeds to suggest further, that, under the modifying influences of draining and burning, there may well be a natural succession from bog→mixed moor→cotton sedge or heather moor, 'the actual paths of change and final results depending partly upon terrain and largely upon the duration and intensity of the agents employed'[4]. The stages of this succession would appear to be illustrated here - but what part drainage has played in the modification of the vegetation is difficult to assess. In various parts there are indications of drainage channels within

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[1] Fenton, E. W., (1952) p. 67.

[2] Pearsall, W. H., (1950) pp. 155 et seq.

[3] Thomas, B., (1935) p. 458.

[4] Pearsall, W. H., (1950) p. 162.

the Eriophorum moor but they are by no means widespread nor intensive. Slight hagging (with channels usually occupied by Sphagnum (see F. 68 (37)), particularly in the central higher and wetter parts of the association, suggest a certain degree of natural drainage. Although his explanation of the tussock habit of Eriophorum vaginatum seems at variance with that of other authors, Fenton offers the most reasonable means of understanding this particular example of Eriophorum moor when, in considering aspects of peat drainage, soil formation and plant succession, he observes that, "where water does not penetrate through the surface of the peat, whether the peat is deep or shallow, it sooner or later influences the vegetation. This not infrequently happens if, after heather burning, there is a surface break down of peat which may then become impervious to water..... If the slope is insufficient to carry any debris then the water passes over the surface making conditions too wet for heather and certain other plants so that mosses, Molinia and perhaps Cotton Grass may become frequent. The result is that heather ceases to be dominant and may ultimately die out".[1] At the lower limits of the Eriophorum association modifications appear to have proceeded even further and the increase of Molinia caerulea and certain dry species, as well as an abundance of Polytrichum commune in the ground layer, might suggest a radical change in the association itself, and herald the transition into another and drier type of vegetation. Suffice it, however, at

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[1] Fenton, E. W., (1952) p. 55.

this stage to conclude that on the basis of form there is some justification for the representation of Eriophorum moor as a separate association - on the other hand, a closer study of its relationships to the other types of wet moorland might make its inclusion with them more reasonable and logical. Its relationships for instance to the Molinia moor are much less obvious. Molinia caerulea is on the whole an even more prevalent species in the Wanlockhead area than Eriophorum vaginatum, occurring as it does in varying amounts throughout practically every association, both wet and dry. It appears to be limited only by altitude, being rare above 1500'. Over certain localities, wider in extent and more concentrated in distribution but at generally lower altitudes than those occupied by Eriophorum moor, the overwhelming dominance of Molinia caerulea necessitates the recognition and representation on the vegetation map of yet another distinct wet moor association - Molinia moor. In the almost complete dominance of strongly tufted Molinia on deep, soft, and wholly amorphorous peat of a depth of at least 2', occupying a position marginal to the main peat areas already outlined and peripheral to the Wanlockhead area as a whole, Molinia moor exhibits certain similarities with the Molinia dominated flow of the Newton Stewart area. As the title moor is intended to suggest, it cannot, however, be considered completely analogous with the 'flow' association, from which it differs in certain aspects - aspects which may well have arisen as a result of differences in site, management, or origin or, more possibly, a complex of all three.

In the Wanlockhead area Molinia moor, in contrast to the Molinia 'flow', is generally associated with slightly drier peat conditions, it occupies a somewhat wider range of altitude and distribution and a greater variety of physical sites and, finally, it differs markedly in its associated species, or rather, in the paucity or absence of species characteristic of Molinia 'flow', such as Myrica gale, Narthecium ossifragum and, to a lesser extent, Juncus articulatus. Also, it is perhaps significant that, as was observed in the south-west, Molinia dominated areas are among those which would appear to have been subjected, at one time or another, to the most intensive artificial drainage in the area as a whole.

The dominance of Molinia and its conspicuous tussocks (never so large or so high as in the Newton Stewart Area) renders the identification of this association comparatively easy and its recognition is further facilitated by its distinctive colour - a hard metallic green tinged with purple, especially in late summer and early autumn, alternating with a silvery-sheen in bright sunlight and when a strong wind smooths out the long vegetation in one direction. However, in spite of the somewhat greater uniformity of composition than was the case in the preceding wet moorland associations, certain variations inevitably arise, the most significant and noticeable of which reveal themselves in the following two samples:-

(1) Molinia caerulea (d) usually strongly tufted on soft, deep and wet peat which very often shows evidence of fairly recent and intensive artificial drainage; accompanied by a variety of other wet moorland species, including -

Sphagnum spp.	widespread, though not necessarily continuous in ground layer.
Erica tetralix	(a)
Scirpus caespitosus	(f-a)
Eriophorum vaginatum	(o-f)
Carex spp.	
Juncus articulatus	(l. f.)

(2) Molinia caerules (d) dominant often to the exclusion of all other species and with well developed tussocks on soft, deep but comparatively dry amorphorus peat. Associated species when they occur are frequently grasses such as Anthoxanthum odoratum, Festuca spp., Agrostis spp., Nardus stricta, together with certain heath plants, Galium saxatile and Potentilla erecta etc. Mosses, and in particular Polytrichum commune are often conspicuously abundant in the ground layer. A few wet species, generally Scirpus caespitosus, may be present but are rarely abundant.

In some instances, patches of Molinia moor may alternate with mixed wet or Eriophorum moor as when peat cutting over an area otherwise dominated by Molinia has resulted in rectangular depressions now occupied by a wetter and often more mixed vegetation. In others, non-tufted Molinia may be dominant but not outstandingly so, in an assemblage of species in which Eriophorum, Calluna and Scirpus may also play a large part. Of the two principal aspects the first (1), much wetter and more mixed has well marked affinities with either mixed wet or Eriophorum moor the second(2) with the dry grass moorland into which it eventually merges. It would fulfil no profitable use to attempt to distinguish between their distribution on the vegetation map however significant these variations may be in other ways.

The vegetation map illustrates (see F. 33) four main characteristics of the distribution of this Molinia dominated moor within the Wanlockhead area. Its position as has already been indicated is practically entirely peripheral. It is most conspicuously and widely developed in the west of the area (it might be noted here that this is also true of Molinia caerulea as an individual species outside this particular association) than elsewhere. In general it occurs at relatively lower altitudes than the preceeding Eriophorum moor and it attains its optimum development at about 1000' and while it frequently extends from 750'-1250' it rarely exceeds 1400'. Within the area thus outlined, Molinia moor is associated with a fairly wide variety of physical sites - a variety much greater than in the case of the other wet moorland associations. Indeed, it can be roughly correlated with four reasonably distinct landform 'habitats'.

(a) "Ridge and spur summits". In the north-west section of the area the ground surface, falling in altitude from 1500'-1700' behind Wanlockhead and Leadhills in the south-east to 1250'-1000' in the north-west towards the Crawick-Duneaton valleys, has been dissected into a number of long broad-backed spurs, or ridges (see F. 24;F. 25;F. 64 (30)). Across their summits where the slope is gentle Molinia moor succeeds Eriophorum or, in some instances mixed wet moor, at lower levels, at altitudes of between 1250' or 1350' to 1000'. Further Molinia often forms a conspicuous fringe on the valley side slopes below these wetter summit associations - provided such slopes are not excessively steep. Not only are many of these valley slopes, consequent upon the less vigorous and deeply cut dissection in this locality, of intermediate gradient - i.e. between the very gently sloping summits (less than 2^o) and the very steep slopes of (10^o-20^o) - but many are, as has been described previously[1], composite, often being interrupted by distinct benches or flats at between 1000'-1250'. On these, the fringe of Molinia frequently becomes wide and very pronounced.

Adjacent, or in closer proximity, to either mixed wet or Eriophorum moor, especially where slopes are very gentle, the Molinia association is usually mixed and accompanied by a wide variety of wet moorland species as in (1). At lower altitudes, where either slope or artificial drainage conditions are more effective, Molinia pure and tufted (2) is wholly dominant and is commonly found in this state over the lower ends of the various spurs (see F. 65 (31)). If the lower valley side slopes are of intermediate slope Molinia may be maintained down into the intervening valleys or merge, by way of a wide transitional zone, into a drier mixed grass association. Where, however, as along the lower courses of the Wanlockhead and Cog burns, river incision is pronounced and the lower valley slopes are very steep the junction between Molinia moor and, usually, dry grass moor is sharp and distinct.

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1 See page 116

(b) 750'-1000' Erosion Surface. Below 1000' Molinia moor is the most prevalent association on the unimproved and uncultivated remnants of that almost level bench so well developed between 750'-1000' in the west and south-west of the area. It clothes a narrow belt on its inner margin which runs along the foot of the main hills from north-west to south-east, some three miles to the north-east of the Nith valley. Here however it is less clearly defined and is of a more mixed composition. In many instances pure Molinia moor alternates with an association in which Molinia caerulea is still abundant but which otherwise possesses many affinities with mixed wet moor. Evidences of peat cutting are widespread and while drainage ditches are frequent, they are all too often blocked and choked with vegetation, either dead Molinia, or Sphagnum spp.. The slope of the surface of this area is slight and possibly at one time some variety of blanket bog covered the whole. Only at its inner margin where there is a marked change in gradient and the steeper slopes of the higher hills are encountered does pure tufted Molinia attain real prominence (see F. 67 (36)).

Two further well-defined, though more localised and restricted sites are provided by -

(c) The 'Glaciated valleys'. The glacially over-deepened 'U'-shaped valleys, with generally broad and flat floors and stepped longitudinal profiles, so characteristic of the Newton Stewart area, rarely find a counterpart in this district. Only to the south-east of the Lowther ridge is there any real suggestion that glacial erosion has modified valley form. Here the short insignificant tributaries of the Portrail Water - the Peden, Potrenick and Glenochar Burns (see F. 23 (7)(8)(9) and F. 64 (29)) - occupy valleys, deep-sided and with broad floors, indeed of a depth and width out of proportion to the length and size of the streams which occupy them. They also exhibit a form more characteristically 'U'-shaped than the majority of valleys dissecting the Wanlockhead area. On their floors and bounding slopes below 1250', liberally plastered with boulder clay and morainic material, and whose gradients are gentle, Molinia moor is generally the most prevalent association. Again, however, these are sites which have been at one time intensively drained and may have formerly been covered with some other variety of wet moor. The Molinia moor of these floors is continued at lower altitudes of 1000'-750' over the ill defined, -

(d) "<u>Terraces</u>" into which they merge along the inner margins of the flood plains of the Portrail Water and Lower Clyde. These terraces vary in width and continuity and would appear to have been largely cut from the glacial deposits which plaster the valley sides. Where such 'benches' are very wide mixed wet moor with abundant Eriophorum may be prevalent, except where artificial drainage is still effective. At the inner margins of these terraces, where gradients begin to increase, or where they are narrow and with an appreciable slope, pure tufted Molinia is usually dominant. But even in these latter instances artificial drainage channels are rarely absent. Similar, but less extensive terraces fringe the narrower flood plains of the lower Glengonnar and Elvan waters, and here again Molinia is often dominant but in far too limited strips to allow its representation on a map of this particular scale.

In its geographical position in the Wanlockhead area, Molinia moor occupies not only intermediate altitudes, but a site, and slopes, intermediate between those occupied by mixed wet and/or Eriophorum moor and the dry grass moorland into which it practically invariably grades. This appears to be corroborated by Fenton[1], whose researches in other parts of South East Scotland indicate that Molinia represents also a stage intermediate in time between cotton grass (Eriophorum) and mixed grass, and that it is generally associated with a drier soil medium intermediate between raw peat and humus, and that it is, in his opinion, a key plant indicative of conditions essentially transitional towards either a drier or wetter stage, rather than any form of climax association. The establishment of such a transitional association depends on a complex interaction of factors, varying in their duration and intensity, among which Fenton suggests as the most important, 1) angle of slope. 2) the level of the water table, particularly during the growing season. 3) biological changes in the peat or soil. 4) grazing in the later phases; and it would therefore be rash, without the support of

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1 Fenton, E.W., (1952) pp. 50-67. In most of the following discussion the status and relationships of Molinia moor is considered in the light of Fenton's discussion of peat, drainage, soil formation and plant succession in South East Scotland.

more intensive ecological studies, to be too dogmatic about the 'raison d'etre' of the Molinia moor here. However, at this stage two possibilities present themselves. First, that in some instances Molinia moor has evolved directly from a wetter association such as the mixed wet moor, or perhaps Eriophorum moor, as a result of an artificial drainage of such a degree as to, under given climatic conditions, favour a slow drying and the establishment of Molinia rather than Calluna. Second, that Molinia moor has established itself on eroded, oxidised and redistributed peat which has been washed down from higher levels and which retains a fairly high moisture content. In both cases, grazing of both sheep and cattle have possibly played an important part in the development.

The significance of the various physical sites which have just been outlined lies largely in the fact that they provide areas of gentle or intermediate slope at low altitudes. The peripheral position of these areas of low altitude bring them within accessible proximity of the farmsteads and have allowed a much greater intensity of drainage than at higher levels and towards the centre of the area. Where, as on the 750'-1000' erosion surface, the degree of slope is often practically negligible, neglect of adequate drainage channels is reflected in a regression from Molinia to mixed wet moor. Also, these sites provide areas of gentle or intermediate slope immediately below the main peat areas whose slope and extent are sufficient to allow spreads of redistributed peat to accumulate and where slope and/or artificial drainage conditions can maintain ground water conditions suitable for vigorous Molinia growth. Such may well be the case at the lower ends of some of the north-west spurs, along the edges of the floors of the glaciated valleys and on some of the narrower river terraces. Here pure tufted Molinia is often dominant and in some cases may even be considered relatively static. Fenton further correlates the vegetation changes discussed, which are moving in the direction of Molinia and finally Molinia with mixed grassland, with certain important biological changes in the soil associated with the chemical disintegration of peat and its final transformation into a black humus type of soil.

In the development and establishment of the intermediate and transitional stage - Molinia moor - landform is a basic factor (and one that should not, although it frequently is, under estimated) in providing areas whose particular angle of slope affects both the nature of water run-off and the position of the water table. It however only 'sets the stage', ultimately the specific type of vegetation which will develop depends on the intensity and duration of the biotic factors. The nature of the Molinia moor area indicated on the vegetation map has prompted this more detailed discussion of its status and must further warrant a much closer study of the biotic factors than this particular study allows, since its potentialities for improvement appear high and, to a very great extent, dependent on judicious management, including careful drainage, and cattle, as well as sheep grazing.

Intermediate Associations. Over the Wanlockhead area Molinia caerulea appears to provide the vital 'link' between areas of dry and wet moor. This species, which for the purpose of classification has been regarded as essentially indicative of comparatively wet conditions, does, however, also make its appearance in some abundance in associations which, on the basis of the quantity of either dry grass or heather on a well drained, dry peat or peaty soil of variable depth, might well be considered dry moorland. Wide areas are often covered by such a mixed vegetation of wet and dry species that it has been necessary to recognise these as intermediate associations (and to record as such on the map) and to distinguish between a mixture of Molinia and dry grass, and Molinia and heather.

Molinia and dry grass. On the basis of Fenton's work[1] and conclusions this mixture would seem to represent also an intermediate stage - correlated with and reflecting certain important biological changes in the soil - in the transition from a Molinia dominated moor to a dry (mixed) association. In the Wanlockhead area it is revealed in two slightly different forms. Either, large prominent tussocks, - occurring individually or in wide compact patches-are scattered throughout an association otherwise wholly composed of mixed grasses - or, less tufted Molinia, abundant but not necessarily dominant, is more evenly and

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[1] Fenton, E.W., (1952) pp. 50-67.

diffusely distributed throughout an assemblage of mixed grasses. In both cases Anthoxanthum odoratum and Nardus stricta are among the most frequent of the other grasses and where the percentage of Molinia is high, particularly in its latter form, it is usually accompanied by very abundant Polytrichum commune - an abundance which is, perhaps, one of the most characteristic features of this intermediate association. Within the regions so classified on the map, every gradation can be seen from an almost pure Molinia grassland to a dry mixed grassland in which Molinia only occurs rarely.

As an association it is never a well and clearly defined one and is prevalent on all grassy slopes of an intermediate gradient which are either affected by the down-wash of acid peat from above or, because of either lack of adequate slope, soil, or climatic conditions, the soil-moisture content is relatively higher than on the pure dry grass moorland. A slight slackening of gradient on an otherwise steep dry grass slope may reveal itself in a striking patch of vivid green Molinia (see F.65 (32)). Its distribution however is more widespread and it occurs most frequently in the west, and north-west, of the Wanlockhead area. In particular, directly north of Leadhills on those long spurs between the valleys of the Snar Burn and Glengonnar Water where, apart from small remnants of either Eriophorum or sometimes, mixed wet moor, a Molinia-dry grass mixture is widespread over sites which elsewhere carry Molinia or Eriophorum moor. It is reasonable to assume that here it may well have been derived from a purer Molinia moor along the lines deduced by Fenton and previously described. Its predominance over Molinia moor in this particular locality may merely be indicative of the more prolonged duration and greater intensity of certain biotic factors operative at these somewhat lower altitudes. It is perhaps worth recording that for many years cattle have been summered regularly in this locality.[1] Yet another factor, which may have some bearing on the abundance of Molinia dominated associations in the north-west, is the more widespread occurrence of boulder clay. With a generous rainfall this superficial deposit especially on intermediate slopes probably allows more effective retention of water than on the steep, impermeable, greywacke slopes. Further south and south-west of this compact area, Molinia and dry grass is the usual association succeeding Molinia moor (and sometimes Eriophorum and mixed wet moor) on lower, and steeper slopes below. In this event the downwash of acid peat is probably one of the most important factors in its establishment.

Molinia and heather is also a frequent and common mixture but, since it usually forms just a narrow marginal fringe to various wet associations and rarely covers such wide areas as the former mixture, its representation on the vegetation map is not always possible and the amounts which have been shown are negligible. Its distribution is related closely to that of mixed wet moor. Generally, at the outer margins of this association, there, where

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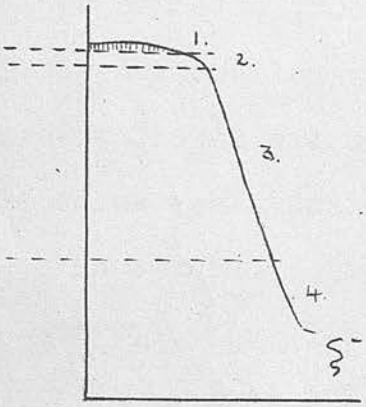
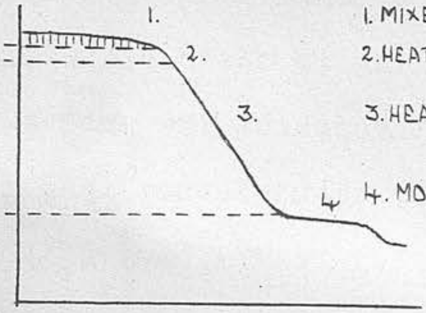
1 One sheep farmer here summers young cattle from a lowland farm near Lesmahagow, from June to September, in return for which the lowland farmer winters his hogs... a practice which was more prevalent in the past than in the present.

DIAGRAM 4.

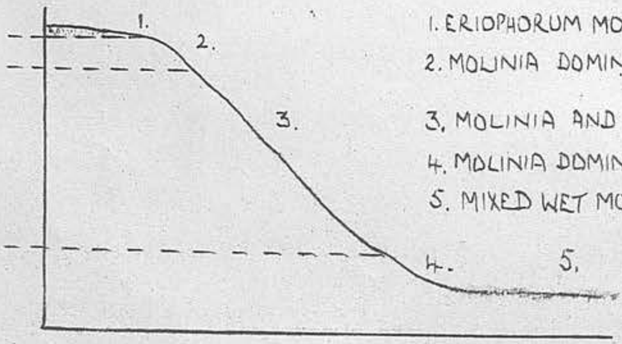
DIAGRAMMATIC REPRESENTATION OF THE ZONATION OF VEGETATION ON SLOPES BELOW PEAT AREAS (NOT DRAWN TO SCALE AND ANGLE AT WHICH SLOPES HAVE BEEN DRAWN ARE INTENDED TO BE RELATIVE AND NOT INDICATIVE OF A SPECIFIC VALUE).



1. MIXED WET MOOR
2. MIXED WET MOOR WITH ABUNDANT MOLINIA
3. HEATHER AND/OR DRY GRASS
4. BRACKEN



1. MIXED WET MOOR
2. HEATHER AND MOLINIA
3. HEATHER - MOLINIA - BRACKEN
4. MOLINIA ON TERRACE



1. ERIOPHORUM MOOR
2. MOLINIA DOMINANT
3. MOLINIA AND DRY GRASS
4. MOLINIA DOMINANT
5. MIXED WET MOOR AND MOLINIA MOOR

lower slopes of the steep well-drained valley sides where it has, at times, completely replaced, or is vigorously invading, dry heather and/or dry grass moorland, with which associations its distribution is closely linked. Under such conditions it is usually, if not completely dominant, evenly disseminated throughout a dry grass or dry heather vegetation. On less steep intermediate slopes, where Molinia is abundant, it is often less abundant and widespread usually occurring rather in compact discontinuous spreads. This distribution is admirably seen on the south-west facing slopes of Conrig Hill[1] where at an altitude of between 1000'-1250' mid-way between the wet moor on gentle slopes above and below - discontinuous patches of bracken are aligned along the steeper slopes where Molinia is frequent, if not abundant. In this connection it is worth noting Fenton's contention that the higher moisture content of broken-down peat soil favours Molinia rather than bracken.[2]

As far as could be assessed, bracken appears in the Wanlockhead area to be limited to those areas of favourable site and slope which occur below an altitude of between 1000'-1250', with the latter altitude as its upper limit of optimum growth for the area as a whole. Such an estimate is however somewhat over generalised and is consistently true only for exposed west and south-west facing slopes, particularly those rising above the Sanquhar erosion surface and the Potrail valley. In the

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1 Map reference /815131.

2 Fenton, E.W., (1952) p.69.

deeply-cut, narrow, sheltered valleys of the southern part of the area it may persist to heights of 1400' or even 1500', though becoming thin and small and only attaining any profusion at such altitudes in sheltered, well drained cleuchs and particularly favoured south facing slopes.[1] The smaller range of dissection as well as wider areas of intermediate slope and soil conditions favouring abundant Molinia, provide fewer opportunities for its successful and widespread establishment in, especially the north and north-west of the Wanlockhead area.

In conclusion, the following table attempts to summarise briefly the principal associations, their outstanding characteristics, and their relationship to the physical habitats of the Wanlockhead area:-

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1 On many of these steep slopes, on the periphery of the area and near to farmsteadings, especially those pre-dominantly grassy, bracken had been or was in the process of being cut. In most cases the operation was being undertaken by hand but in one a mechanical cutter was in use on a slope of at least 20°.

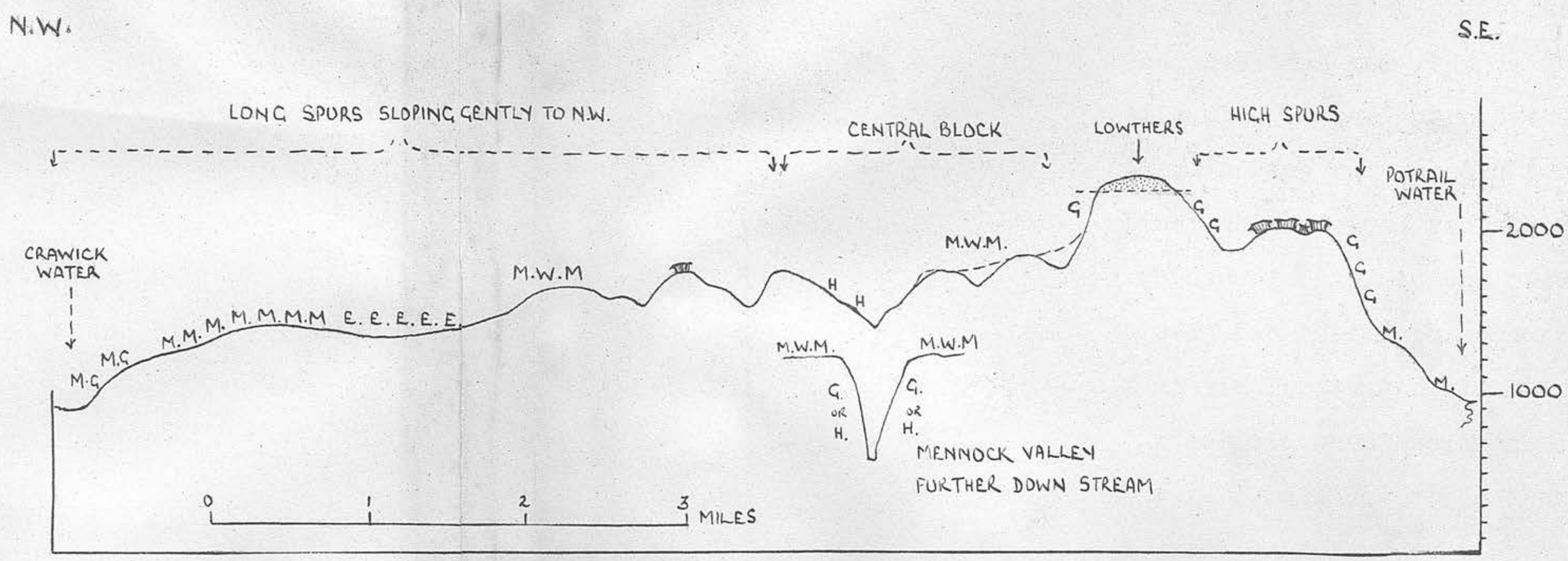
Associations	Physical (landform) Sites	Regional distribution	Other factors affecting or which have affected, the associations
1. Summit Vegetation	Narrow exposed summits generally over 2,250' from which either pre-existing peat has been eroded or on which exposure and lack of a sufficiently wide site has prevented the accumulation of peat.	Aligned N-S. Capping Lowther ridge	Grazing, but only for a short period in summer, even then sheep are discouraged from remaining for too long at these high altitudes.
2. Dry Moorland (a) Dry Heather (b) Dry Grass (c) Mixed Heather and grass	Closely related in composition and physical requirements. Occupy similar sites - well drained steep, over at least 10^{o} though usually exceeding 20^{o}; essentially slopes which allow rapid run-off and drainage and which prevent downwashed peat from accumulating; purest development often association with steep slopes of high altitude above which there is no peat cap - particularly significant in the case of dry grass - otherwise its greater proportion intimately related to the affect of biotic factors. - Below 1400-1250' bracken prevalent -	Widespread, but concentration in south-south west and with extensions northwards over Central belt	Sheep grazing Heather burning Soil creep)aggravated)by above Slope)on very erosion)steep slopes rabbit grazing cutting
3. Wet Moorland	Areas below 2000' where degree of slope was such as, at some time, to prevent adequate run-off and drainage and result in establishment of 'blanket-bog'. Locus of such areas have often slopes of < 2^{o}.		
(a) Hagged peat	Small, gently sloping or almost flat areas, over 1750'	High spurs to S.E. of Lowther ridge and on highest summits in Central belt.	Natural drainage and erosion burning of heather grazing? limited.
(b) Mixed Wet Moor	Wide areas of gentle or negligible slope between 1250'-1750' Wide river terraces and gently sloping areas of 'bench land' < 1000'.	Central belt	(Heather burning (Sheep grazing (Peat cutting (Limited amount of (artificial draining

Associations	Physical (landform) Sites	Regional distribution	Other factors affecting, or which have affected, the associations
(c) Eriophorum Moor	Wide gently sloping areas 1500-1250': frequently situated between (b) and (d)	N.W. Belt	(Burning probably in (past (Spring grazing especially (Some drainage (Some natural erosion
(d) Molinia Moor	Wide areas of gentle or intermediate slope 1000'-1250/1300'; glacial deposits often widespread at lower altitudes ; Areas of gentle slope (erosion surface 750-1000') under 1000'- - narrow terraces of glacial material-floors lower slopes of U-shaped glaciated valleys.	N.W. Belt and south-west! generally peripheral	Artificial drainage always Grazing - sheep (Cheviot and Blackface) and cattle in summer months ? burning Peat cutting - sometimes
4. Intermediate Associations			
(a) Molinia - Dry Grass	Gentle or intermediate slopes at low altitudes 1300' where superficial deposits (mainly glacial debris) frequent; or intermediate and fairly steep slopes considerably affected by downwash of peaty soil.	N.W. belt and on slopes in West and south-west	Grazing - sheep and cattle in summer months ? (draining on the (peat (burning on the (peat possibly pronounced and advanced biological soil change
5. Molinia-Heather	Intermediate slopes steeper than above but not so steep as in (2) which occur below a peat area	Widespread	Burning Sheep grazing

Only in the "summit vegetation" is there any approximation in the Wanlockhead area to a climax vegetation whose distribution and character is dependent wholly on existing physical conditions of high altitude, considerable exposure, and climatic conditions, which limit the growing season to less than 160 days. Even here, however, the vegetation is not entirely free from grazing influences and the possibility that it may have been derived from a former peat-cap which has since been completely eroded

DIAGRAM 5.

CROSS SECTION DRAWN ALONG SPUR SUMMITS FROM S.E TO N.W. SHOWING GENERAL RELATION OF ASSOCIATIONS TO LANDFORM



LEGEND

SUMMIT VEGETATION

HAGGED PEAT

M.W.M = MIXED WET MOOR

E.E.E. = ERIOPHORUM MOOR

M.M.M = MOLINIA MOOR

M.G = MOLINIA-DRY GRASS

H. = DRY HEATHER

G. = " GRASS

and removed must not be overlooked. Although the areas of wet and dry moorland are closely related to the particular slope conditions provided by the landforms of this area, their present specific character is largely the result of a complex of biotic factors. The various associations of the wet moorland have, probably, been derived from a more uniform type of blanket bog, initiated originally on all gently sloping, ill-drained areas under what may have been conditions of rainfall higher than prevail to-day. Their altitudinal zonation - striking, though not necessarily perfectly repeated everywhere, would appear to be dependent largely upon the increasing effects of erosion, soil wash and biological change, and man's interference, with decreasing height and greater accessibility. The predominance of Molinia particularly in the west of the area, as the 'key' transitional association and species in the change of vegetation on the wet moorland, may also be favoured by high rainfall, the greater retention of water on areas underlain by glacial deposits and the wide development of areas of intermediate slope. Similarly, the higher proportion of dry grass on steep slopes is the result of biotic factors acting on physical sites favourable to its development.

Therefore, in so far as landform sets the stage it must also, to a lesser extent, influence the course of the vegetational changes initiated by other factors, and in the Wanlockhead area the distributional pattern of the vegetation associations bears a close relationship with landform primarily expressed in altitude and slope conditions. (see Diagram 5, opposite.)

SECTION IV

THE PEEBLES AREA.

CHAPTER IX.

The Geographical Introduction to the Peebles Area.

Geology and Landform. The final area chosen for study was that well defined block of upland country (see F. 34) directly north of the River Tweed and bounded by the valleys of the Eddleston Water to the west and the Gala Water to the east, which has, for convenience, been designated the Peebles Area. Situated some thirty miles north-east of the Wanlockhead area and separated from it by the massive heights of Broad Law (2754') Hartfell (2651') and Dollar Law (2680') and with its northern boundary coinciding with the pronounced, steep, fault-scarp of the Moorfoot edge, it abuts directly on to and overlooks the East Central Lowlands of Scotland; further, this particular area offers the most eastern sample of hill land comparable in general altitudes and extent with the two preceding areas. Certainly the high ground of the Southern Uplands is continued farther eastwards to the coast by the Lammermuirs but east of the Gala Water altitudes are somewhat lower, decreasing steadily in that direction and the proportion and variety of rough hill grazings are correspondingly smaller.

Geologically, the Peebles area is comparable and closely related to both those of Wanlockhead and Newton Stewart, being underlain by a continuation of the same belt of Lower Palaeozoic sediments. (see F. 35) It differs from them only in its more uniform rock structure and composition and in its more northerly position, with the result that the Southern Upland Boundary

Fault, along whose line the Carboniferous and Old Red sediments of the Central Lowlands are separated from the Lower Palaezoic Ordovician and Silurian sediments of the Southern Uplands, coincides with its northern boundary. Once again, highly and complexly folded, steeply-dipping Ordovician and Silurian greywackes, interleaved with varying thicknesses of mudstones and shales, strike from north-east to south-west across the area, and the apparent simplicity of this geological structure and composition is interrupted, only occasionally in the northern belt of the Ordovician strata, by elongated lenticular inliers of black shale, cherts and associated lavas. Other rock types are represented by numerous but relatively small igneous dykes, largely felsitic, and minor porphyritic or granitic intrusions, both most liberally scattered through the southern belt of Silurian sediments, trending in a direction parallel to that of the Caledonian strike of the sedimentary rocks and attaining a degree of concentration only over a small area directly north of Innerleithen. Two major faults are worthy of note - the Southern Upland Boundary Fault already mentioned, with which the pronounced fault-line scarp of the Moorfoot edge is so closely associated and that fault, conspicuous for its length, which aligned from north to south along the line of the Dewar - Glentress - Leithen Waters may well have facilitated the formation of the continuous and well marked furrow which all but bisects the area.

Here, as in the Wanlockhead area, these Lower Palaeozoic sediments have been carved into a high, deeply dissected, smoothly contoured, massive, plateau-like block of hill ground whose gently undulating upper surface attains a general maximum altitude of between 1750'-1800', with occasional broad swells rising to 2000', and with a gradual over all slope from 1750' in the south-west to 1250'-1000' in the north-east. However, as in the Wanlockhead area, the landscape is essentially polycyclic, and the plateau-like form similarly composite in character. While accordance of summit levels suggests a grouping of former base levels of erosion closely analagous to that of the preceding area - the areal extent and the distribution of areas of gentle slope at such levels is appreciably different within the Peebles area.

Disregarding for the moment the numerous valleys which dissect the area and considering only the summit altitudes of ridges, spurs, and hill tops, at least three well-marked groups of accordant summit levels reveal themselves between the following altitudes -

1. 1750'-1850' rising in places to 2000'+ and falling gradually and gently to 1500' - with a suggestion of an intermediate and at times distinct level between 1500'-1600'.
2. 1350'/1400' - 1000'/1250'.
3. 900'/1000' - 750' -

and separated from each other by areas of steeper slope. The existence of these three groups of accordant summit altitudes, clearly visible in the field and on a 1" topographic map, are further, graphically illustrated by the series of projected profiles which have been constructed from north-west to south-east across the area (see F. 36) and which serve to indicate figuratively not only their spatial relationships but, of vital and primary importance, the extent to which areas of gentle slope may actually occur at these altitudes.

Straddling the Peebles area from the Moorfoot edge in the north-west to the Caddon "embayment" in the south-east is a central block of country across which summit altitudes are generally of a high order, between 1750'-1800' , rising in several places particularly along the line of the Gala - Tweed watershed to 2000', and falling gradually to approximately 1500' to the north-east and to the south-west. In these two directions respectively this central high "plateau" is succeeded and is fringed by areas where accordant summit levels are of a lower order varying from 1350'/1250' to 1000'/900' above either the Gala or Tweed valleys. This area of lower summit altitudes is more widely developed in the north-east, below the level of the high "plateau" and above the steep right bank of the trough of the Gala Water - becoming more noticeably extensive in the north-east in the vicinity of the lower Heriot Water. It is paralleled by a similar but somewhat narrower fringe, at times hardly perceptible, above the left bank of the Tweed extending into and becoming broader above the Eddleston valley - and which, with a general altitude of 900'-1200' is separated from the high "plateau" to the north by steeper slopes. Further, the steep north-facing slope of the Moorfoot scarp separates clearly, and indeed abruptly, these essentially upland areas from the lowlands of the north-west, generally, but not entirely, developed on less resistant sediments and where summit levels are between 1000'/900' - 750'.

This composite plateau with its different summit levels has however been deeply bitten into and relatively maturely, if somewhat unequally, dissected by the present net work of valleys - tributaries of either the Tweed, Eddleston and Gala rivers and to a lesser degree by the head streams of the North Esk river in the north-west. What may well have been originally a continuous and gently sloping plateau surface (or surfaces) has been reduced to a series of elongated ridges or lumpy hills whose generally steep smooth bounding slopes culminate in broadly rounded, gently convex summits, but of varying breadth, height and steepness, and whose diverse trends are solely the result of the irregular and often close net work of river valleys (see F. 37). Most of the principal rivers and their major tributaries cut across the area in a variety of directions conspicuous largely by the absence of any apparent relation to underlying rock structure. Only in the north-west of the area does the north-east → south-west alignment of, for instance, the Heriot water and its tributaries, and some of the smaller right bank tributaries of the Gala water, suggest a development of a drainage pattern influenced by the strike of the underlying Ordovician strata. Elsewhere valley lines exhibit many trends of which two predominate, either from north to south or from north-west to south-east.

The present valley forms, (see F. 39 and F. 40) while often composite, are essentially modern and still relatively youthful features. Their narrow, and often strikingly flat winding floors are hemmed in by usually steep, lower valley slopes, succeeded above by gentler convex slopes which eventually merge into the smoothly rounded ridge and hill crests and a wide shallow 'V'-form replaces the narrower and deeper notch of the lower valley form. Such valley slopes are commonly 'composite', their otherwise smooth steep even slopes being interrupted by one or more distinct, though normally limited, benches or flats of a more gentle gradient, before the final summit brow is attained. Their rivers, maturely and evenly graded meander vigorously across the narrow floors where the covering film of silty alluvium often conceals a deeper in-filling of coarse gravels. Lateral corrasion is active and vigorous where the swinging meanders impinge on and often under-cut the steep bounding slopes - in some cases exposing solid rock, in others, where glacial debris mantles the lower slopes, resulting in the slumping and the laying bare of the unconsolidated material in steep broad concave scars. Occasionally slight irregularities break the even continuity of the otherwise smoothly graded river courses. Many are evenly graded practically to their source with the valleys terminating in wide open shallow 'V'-shaped heads. In others however the head waters are characterised by youthfully steep gradients and the valleys head in the deep, steep-sided, flat-bottomed 'hopes' so typical of the eastern Southern Uplands, and whose steep upper slopes are often savagely gullied by active headward erosion and rapid run-off (see F.69 (43)).

The degree of dissection, the depth and width of the valleys and the concurrent survival of the gently sloping surfaces of the original plateau vary very markedly however as between the south-west and the north-east of the Peebles areas - (variations strikingly comparable in their form, distribution and cause to those outlined in the Wanlockhead area) - very largely as a result of the difference in the altitude of the base levels of erosion provided, on the one hand, by the River Tweed and, on the other, by the Gala Water, and their respective tributaries. The present valley floor of the middle Tweed, it should be noted, from Peebles almost to Caddonfoot[1] has been cut down to an altitude of between 400'-500' and the floors of the lower Eddleston and lower Leithen Waters, directly above their junction with the Tweed, are at an altitude of between 500'-750'. In contrast, the present floor of the Gala Water north of the junction of the Luggate Water is everywhere over 500' and rises to 800' at the junction of the Heriot Water - the lower courses of these two major tributaries of the Gala standing at altitudes of between 600'-750' and 800'-900' resepctively. The advantage possessed by those rivers graded to the lower base level of the Tweed - Eddleston - Leithen Waters is responsible for the difference in the depth and degree of dissection as between the south-western and north-eastern

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1 Map reference /450351.

parts of the plateau - differences which reveal themselves primarily in 1) valley form, 2) the extent and form of summit surfaces, and 3) the distribution and prevalence of steep slopes.

South-west of that watershed which, striking from north-west to south-east along the axis of the highest summits, separates the Tweed - Eddleston drainage from that of the Gala Water (see F. 37), valleys are characteristically deep, often some 750'-1000', widely and markedly 'V'-shaped with high, unbroken, even slopes of a gradient commonly 20° or over. Valley floors are flat, narrow and restricted, except in the case of the lower Leithen Water, and terminate in deep, steep-sided 'hopes'. The mature dissection by these deep broadly 'V'-shaped valleys, typified by such as the Leithen Water, Walker Burn and GatehopeKnowe Burn (see F. 39 (12)(13)(15)), has all but destroyed the southern part of the original plateau surface and has reduced it to a series of irregular, winding, narrow ridges, bounded by high, very steep slopes which finally culminate in narrow, gently-domed, convex summits whose altitudes decrease gradually from 1900'-2000' in the vicinity of the watershed to 1250'-1000' in the south and south-west. These ridge crests are in addition extremely irregular and undulating in form, interrupted by cols often as much as 200'-250' below the culminating points and with the latter occasionally, as in the case of Makness (1912')[1] and Sheildgreen Kipps[2] (see F. 69 (38)), exhibiting a more sharply outlined peak-like form than the more generally prevailing smoothly

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[1] Map reference /278447.

[2] Map reference /282444.

rounded summits. Narrow, parallel and closely spaced, aligned from north to south and separated by deep steep-sided valleys, these ridges are most perfectly developed between the Horsburgh Hope and Gatehopeknowe Burns. Not only are valley sites restricted and areas of gentle slope on the summits negligible (see F. 41) but the proportion of the area occupied by very steep slopes is remarkably large (see F. 42). At the lower ends of these spurs, truncated by the incision of the rivers Tweed - Eddleston, benches or 'flats' of small slope , remnants probably of a former and higher valley floor, survive at between 1350'-1000' approximately, of small extent above the north bank of the Tweed, broader and less dissected above the left bank of the Eddleston Water. Only near the watershed, where dissection by the left bank tributaries of the Leithen Water is not so close, do the broad, more massive ridges of Totto Hill,[1] and Whithope Law[2] retain appreciably extensive remnants of what was once a high, gently-sloping plateau surface of between 1750'-2000'.

North-east, however, of this watershed the degree and intensity of dissection are much less pronounced and the resulting landforms exhibit a striking contrast with those of the southern part of the area. Graded to higher base levels the principal valleys (see F. 37) which ramify the northern part of the area rarely exceed 500' in depth and their floors, while still flat and narrow, are generally over 800'-1000' high. Lower valley side slopes are steep, commonly of gradients between 10°-20°,

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1 Map reference /306453.

2 Map reference /326446.

markedly convex above and grading, often by a more or less pronounced break of slope or 'brow', into areas of gentle slope above 1250' or 1500' (see F. 40). The evenly graded, meandering burns rise usually in wide shallow valley heads. On the interfleuves wide, convex areas of gentle slope are preserved, but slightly dissected by the smaller and still youthful tributaries and head waters. Directly north of the watershed much of the original high plateau surface is preserved in broad extensive areas of gentle slope between 2000' and 1750' from which narrower, but still fairly broad, ridges project north-eastwards, decreasing in altitude to 1500'. Still farther north-east and east, these high plateau remnants are replaced by a broad fringe over which generally lower altitudes prevail and which slopes gently eastwards from 1450'/1350' to 1000' approximately. Into this surface the Heriot, Luggate (see F. 69(39)) and Gala Waters have cut well defined furrows, with steep valley side slopes, generally below 1000'. Elsewhere, dissection is youthful and relatively slight and considerable areas of gentle or intermediate slope between 1000' - 1250' are preserved on those low broad spurs which trend from south-west to north-east above the right bank of the Gala and Luggate Waters (see F. 41; F. 42; and F. 69 (45)).

Bordering this unequally dissected plateau to the west, south, and east, are the deeply cut meandering troughs of the Eddleston, Tweed, and Gala Waters, their steep confining slopes broken only where they are joined by lateral tributaries. Their floors, narrow and restricted, seldom exceeding half a mile in width, are often considerably less and, at times, may be practically reduced to the width of the river as along the deep, constricted defiles at Elibank[1] and Galashiels[2]. Their narrow ribbons of slightly terraced alluvium are continued as slender threads up the major tributary valleys. Along the north bank of the Tweed discontinuous terraces of fluvio-glacial sands and gravels rise to heights of 50'-100' above these alluvial haugh lands and merge into uneven spreads of till on the lower valley-side slopes behind. Widespread, and of considerable depth on the lowlands to the north-west, glacial deposits within the Peebles area are concentrated largely in the west (see F. 43), along the lower slopes of the Eddleston valley and its tributaries - extending up to, though rarely exceeding, 1000'. Eastwards and within the upland area proper, till (boulder clay) is sparsely scattered on the lower western slopes of the wider tributary valleys where, often severely undercut by lateral river corrasion, it may form a narrow ill-defined bench or terrace on that side of the valley. The former presence of the Pleistocene ice sheets, whose movement in this area is generally assumed to have been from west to east, is evidenced only in these scattered peripheral deposits of till and fluvio-glacial sands and gravels. Even the smoothly flowing contours of the eastern Southern Uplands, once attributed to the moulding and smoothing action of ice, is now generally ascribed to weathering under normal climatic

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1 Map reference /399359.

2 Map reference /490360.

conditions.[1] Only in the slight Caledonian ridging which scours some slopes and summits in the extreme south-east and the occasional deep, but waterless, furrows and defiles cutting either across watersheds or along valley slopes, bear witness to the erosional effects of either ice or its meltwaters.

Primarily on the basis of summit altitudes and the degree of river dissection Linton has defined several physical regions, or what might more profitably be called physical sub-regions, in the Peebles area, whose distribution is indicated on a reproduction of his map[2] (see F. 44). Only three of these regions directly concern the area under discussion, and his succint notes on their general physical character[3] provide a comprehensive and fitting summary of the outstanding landform features of the Peebles area.

1) <u>The Leithen Plateau</u> - a well dissected upland region transitional in character between the high plateau and dissected plateau region presents two distinct aspects a) the northern plateau, less deeply dissected: has broadly convex ridge crests, without any abrupt brow, covered by widespread and continuous peat or hags which overlap down upper slopes to 1750': valley slopes moderately steep and steepen downwards, with shallow open 'V'-form

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1 Linton, D.L., and Snodgrass, C.P., (1946) p. 386: It is, however, also worth considering whether the smoothness of slope and the often thick aggradation of coarse detrital material along the valley floors may not be, in part, ascribed to intense frost shattering and widespread and very active solifluction under peri-glacial conditions in immediately post-glacial times.

2 Linton, D.L., and Snodgrass, C.P., op., cit. (1) p. 408.

3 Linton, D.L., and Snodgrass, C.P., op. cit. (1) pp. 411-416.

at valley heads. Topography generally subdued. b) the souterhn plateau - deeply dissected by Leithen drainage; ridge crests narrow and undulating with cols 250' below cluminations which are occasionally sharply outlined; summit peat virtually absent; valley slopes steep, commonly deep, valley heads usually nivated amphitheatres.

2) Upper Gala Region: Polycyclic upland, hills rounded and subdued with summits 1200'-1500' and slopes above the 1000' level, always gentle: below 1000' valley slopes are relatively drift-free and moderately steep, even with occasional screes, and descend abruptly to the haugh lands of the main valleys.

3) North Tweedside: A region of hill and valley slopes unified by the through-flowing Tweed: a former Tweed valley floor at about 1200'-1300' has been dissected to give a series of long spurs cut off by rising ground at proximal ends, by truncated spurs at distal ends and with gentle drift-free slopes towards the intervening laterals.

Although primarily concerned with a genetical classification and description of landform, Linton has thus, keeping well in mind the importance of physical sites in any consideration of land use, outlined a regional sub-division of the landforms of the Peebles area which can hardly be bettered as a basis for the geographical study of the distribution of the principal vegetation associations - a relationship which he all too briefly, but none the less pertinently, observes and suggests, and which will be more fully considered in the following chapters.

Finally, in what Linton describes as its "rounded and well modulated 'outlines'"[1], in its composite plateau-like form and general accordance of well-marked summit levels, and in the contrasting dissection of its northern and southern parts, the Peebles area is, in its physical form, very similar to the dissected table-land of Wanlockhead. The significant difference lies in the greater proportion of the Peebles area which stands above 1000', and again above 1500', and above all, in the considerable preservation of high plateau surfaces of gentle slope over 1750'-1500'.

<u>Climate.</u> As in the former areas, only a very general, and necessarily incomplete, appreciation of the climatic conditions can be gathered from the very variable records available for stations without or peripheral to the Peebles area. The only two stations for which long term averages of meteorological elements are available, West Linton (820') and Blackford Hill (Edinburgh) (441'), lie well without and to the north of the area surveyed, in an essentially lowland region. Elsewhere, quantitative data are provided by scattered and often incomplete records from stations, few of which, although in close proximity to the area, cover periods long enough to provide reliable averages, or if they do, are for periods of an early date, well within the last century.

However, from a general climatic point of view the Peebles area (see F. 45) must claim a certain measure of individuality primarily on account of its lower annual rainfall. Although in

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1 Linton, D. L., and Snodgrass, C. P., (1946) p. 386.

its culminating points the plateau never attains the maximum altitudes of either the Newton Stewart of Wanlockhead areas it is nevertheless more massive than either of them, with a much greater percentage of its surface lying between 1500'-2000'. Its north-easterly position at the edge of the Southern Uplands leaves it completely exposed to the north-west and the north-east and also to the east, where altitudes are everywhere lower. It lies, however, in the lee of that high shoulder of upland between the Tweed and Middle Clyde where the summit plateau stands well over 2000' - a position which must tend to accentuate the rain shadow effect of its more easterly position and account for its relatively low average annual rainfall of between 35"-40", with a maximum of probably, though rarely exceeding, only 50" on the highest summits (see F.46). The increase of rainfall with altitude is most pronounced along the north-western Moorfoot edge. Over 1000', at least half the area surveyed has an average annual rainfall of between 35"-45"; the western part with its generally greater height has an average of between 45"-50" on the high plateau over 1500', while the lower plateau between 1500'-1000' in the east and north-east receives a slightly lower average of about 40". The deep valleys of the Eddleston, Tweed and Gala are drier enclaves with annual averages of 30"-35".

The seasonal distribution parallels that of the preceding areas, with the winter months of October to March receiving approximately 60% and the summer months of April to September, 40% of the total amount. Of an average annual total of 225 rain days, a mean of 20 days is common in the winter months and again in August, as against a monthly mean of 17 days in summer months, except in June and September when the average number of rain days is 14 or between 14-17 respectively. The mean monthly maximum of either December or January below 1000' is of the order of, though rarely exceeding, 3.5" - 4" while the secondary maximum of August usually equals and indeed often exceeds that of the winter and is here inclined to be more noticeably pronounced than in the other areas. Long-term averages reveal the usual dry spell between April and June, when the mean monthly minimum below a 1000' is usually less than 2.5", and the correspondingly low monthly average again in September.

Temperature records (see F.47) are less numerous and less complete than those for rainfall. Apart from those for Edinburgh and West Linton the sea level values provided by the Climatological Atlas of the British Isles, while affording a basis for comparison with the other areas, give values of too high an order for this essentially upland area, and only the long term averages produced by Buchan[1] for stations close to the periphery, while covering the early period of 1856-1895, allow a closer approximation of the actual temperature conditions between 500-1000'. The average mean annual temperature varies from 43°-45°F in contrast to 47°F for the district as a whole, and with an annual range of 20°-21°, the means of the coldest month (January) range between 34°-36° (39° for the district as a whole) and those of the warmest month

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(July) between 56°-54° (58° for the district); and further, there is a range of some 30°-33° between the mean monthly maxima for the warmest month of between 63°-65° and the mean monthly maxima of the coldest month of between 30°-33°. These temperature figures, however, with their indication of a growing period of between six and seven months, are generally comparable with those for the Wanlockhead district as a whole, and similarly, do little to reveal the harshness or length of duration of winter conditions on either the high or low plateaux, though they must come near to the latter: in the former case, where averages at 2000' must be approximately 4°-6° lower than those of the surrounding lowlands and valleys, temperature values of the following order probably prevail -

1)	mean annual temperature	40°F	
2)	mean temperature of coldest month	32°F	(mean minimum 27.4°)
3)	" " " warmest "	52.4°F	(mean maximum 59.9°).

While five months may have mean temperatures over 42°F in only two do mean minimum values exceed this figure, and for six months of the year mean minimum temperatures may be less than 32°F. The severity and length of winter conditions are characteristics which the Peebles area shares with that of Wanlockhead - with an average for the district of 100 days with minimum temperatures below 32°F and average dates for the first and last screen frosts at 15th September to 1st October and 15th May respectively.

Likewise, snowfall amount and duration is comparably high, snow falling on low ground on an average of 30 days between November and April and covering the ground on an average of from

20 - 50 days, according to altitude, within the same period. Snowfall is, however, as variable an element as rainfall and the average of 50 days for higher altitudes is probably a fairly conservative one and gives little indication of the extreme conditions experienced by this area, of which it has been said "snow lies longer in Peeblesshire and Selkirkshire than anywhere else south of the Highland Line[1] - particularly in the north-west of the area where heavy falls and bad drifting are most common.

Although the average date of the last screen frost appears for the district as a whole to be slightly earlier than in the Wanlockhead area, early spring conditions are nevertheless usually severe and variable. The eastern exposure makes it particularly susceptible to the cold, biting, east winds, characteristically frequent at that time of the year, which often impose a severe check on plant-growth and may, in some instances, even carry the east coast 'haar' along and over the Moorfoot edge as far west as the Eddleston valley, resulting in low temperatures accompanied by chill, damp, winds in April, May and June. Also, the often prolonged dry spells during these months, while providing the necessary and ideal weather conditions for heather burning, may not only retard growth and 'burn-up' hill pastures at this period so vital to sheep farmer but also, under the drier

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[1] Linton, D.L. and Snodgrass, C.P., (1946) p.392. It is also worth remembering that during the severe winter of 1947 this area was one of those particularly severely hit. The occupants of Blackhope Farm (1100'), south of the Moorfoot edge, were snowed in and house-bound for twelve consecutive weeks.

conditions of the eastern Southern Uplands, particularly if preceeded by an exceptionally dry winter, increase the danger of severe over-burning and its concomitant evils.

Land Utilisation. In the general outlines of its landforms and in the severity of its winter climatic conditions the Peebles area possesses certain broad characteristics in common with that of Wanlockhead. True lowland sites are restricted and a high, indeed somewhat higher than in the preceeding area, proportion of its surface stands well over 1000'. Nevertheless, one of the probably most outstanding features of the landscape of this eastern area is the amount and above all the altitudinal extent of improved agricultural land of one kind or another (see F.48).

Easily cultivable sites at low altitudes - less than 500' - are at a premium and are provided only by the narrow continuous ribbons of alluvial haugh land, occasionally bordered by sandy terraces, which floor the Eddleston, Tweed, and Gala valleys. These haughs often liable to flooding, carrying a relatively high percentage of permanent pasture, and with arable fields usually on the lighter soils of the higher terraces or at the margins of the valley floor, are hemmed in by commonly steep valley side slopes from 500' up to 750'/1000', or more in some instances. Where not excessively steep (i.e. less than 10^{o}-15^{o}) and especially where covered with till, most of the arable cultivation is very largely concentrated on such valley-side slopes and, indeed, on such sites whose steepness in other regions might well have discouraged the plough. Farm steadings are commonly situated where the junction of a lateral tributary with the main valley affords a wide embayment, with the 'core' of their arable land on the slopes above. The steeper of such slopes (especially on the north bank of the Tweed,) remain as permanent grassland, occasional wooded policies or, in less frequent instances, carry rough grass or heather moorland down the whole slope to the level of the haugh or terrace-land below. Above 750'-1000', these steep valley-side slopes commonly flatten out to give areas of somewhat gentler gradients on the spurs above the main valley. On such higher benches, of varying extent and continuity, which fringe the central high plateau, and particularly over those where either a spread of till or deeper weathering of the more friable rocks provide any reasonable depth of soil (commonly light, stony, rarely over 8"), arable and improved land extends often up to 1150' -1250' or, in exceptional cases, as high as 1300' (see F. 69 (45)).

The actual extent, and the maximum upper altitudinal limit of improved land varies, however, very considerably throughout the area, in accordance with the uneven development of these particular sites. As previously indicated[1] those benches above the north bank of the Tweed are often very small, narrow, and widely separated, and it is here that, in many cases, improved land frequently reaches an upper limit at 1000'-750' or even 500', and where, also, arable cultivation often occurs on some of the steepest slopes in the area. It is the wider and more extensive

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[1] See page 179.

development of low spurs above the Eddleston and Gala Waters (and also in the Caddon 'embayment') with areas of gentler slope between 750'/1000' - 1250' and a more generous covering of till that accounts for the broader, more continuous fringes of improved land and for the relatively higher altitudes to which cultivation has been pushed to the east and to the west of the area. The upper limit of improvement varies too widely from a minimum of 500' to a maximum of 1300' to allow any useful generalisation to be made regarding the limiting factors in operation. The maximum upper limits appear to be determined either by the steeper slopes of the high plateau behind or merely by the increasing concentration of a complex of a diverse factors, such as poorer and thinner soils, the inevitably harsher climatic conditions and the greater difficulties of access with increasing heights. In some cases, fields of either oats or turnips were noted as high as 1200' - in others, there was evidence of upper fields, once probably ploughed, having been left as permanent pasture or of having been abandoned to the gradual encroachment of heather or rough grass moorland. More often these higher-lying fields are managed under a considerably longer ploughing rotation than those at lower altitudes and on slightly gentler slopes nearer the farmer steadings. The amount and extent of improved land along the Gala-Eddleston Waters where steeper slopes at least provide a greater measure of natural drainage, offers a marked striking contrast with the Moorfoot Bench in the north-west. Here altitudes rarely exceed 950'-1000' and the underlying rock is completely masked by a continuous mantle of glacial debris. Wide areas however of gentle gradient with impeded drainage resulted in the past in the development of thick, acid peat now generally modified by artificial drainage, but which still remains largely under rough grazings; land improved and cultivated either at present or in the recent past mainly concentrates on those discontinuous mounds of fluvio-glacial sands or on those low swells, which diversify the monotony of what Ogilvie has called the higher Lowland Peneplane[1].

That in the east, south and west of the Peebles area - an essentially upland district - man has, in the face of what are indeed difficult physical conditions, carved out a considerable area of improved agricultural land - its extent and its varying altitudinal limits must be very largely a measure of his individual effort. This hard-won fringe of improved land with its large regular pattern of fields, blocks of coniferous or mixed woodland, scattered shelter belts and wooded parklands, forms the basis of a peripheral belt of large semi-arable, mixed stock rearing farms. Marginally situated between the haugh lands and the higher hills, 40%-50% of their usually large acreage (of an average of between 700-1000 acres), may consist of rough hill grazings. On the one hand, the rough hill grazings form the main-stay of breeding herds of Blackface ewes, while on the other, the arable and improved 'park'[2] land supports a usually large number and variety of stock

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1 Ogilvie, A.G., (1930) pp. 425-6.

2 The term 'park' is commonly used in Scotland - especially in hill districts in the south for any enclosed improved grassland.

which includes Cheviot and cross-bred ewes, with cross-bred and/or Suffolk or Oxford cross lambs in the summer and on all, except those farms with a particularly small acreage of arable land, substantial herds of breeding cattle - usually Galloways, Galloway crosses or Aberdeen Angus - Shorthorn crosses. Functioning as two almost separate economic units, the hill and arable land of these marginal land farms are, in some cases, complementary, as when the less hardy Cheviot ewes which may be summered on the hill ground are fed in winter on the enclosed parks and when cattle run on the hill often from May or June until the beginning of November[1]. Assured of prices for their stock which will justify the amount of labour and energy that must be expended on arable cultivation under such difficult physical conditions, these farms must make an invaluable contribution to the country's meat supply, and further, on their prosperity must depend to a large degree where the dividing line between the improved and unimproved land will be situated.

In the heart of the Peebles area - the high plateau where a high proportion of the ground lies over 1500' - improved land occurs only as small scattered patches of 'in-bye' around farm steadings and shepherds houses and, usually confined to the lower reaches of the larger and more accessible valleys, is frequently situated over 1000'-1100'. It represents however a negligible

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[1] It is perhaps surprising to find in view of the climatic conditions that on a number of these large farms it is the practise to keep the cattle out of doors all winter in near-by fields where they are fed on silage.

percentage of the total acreage of the large - averaging some 2000-5000 acres - hill sheep farms which completely dominate this central part of the area. With a stocking of approximately 2-3 acres per breeding ewe, they are concerned primarily and, indeed, solely with the breeding of Blackface sheep. Occasionally, on those sheep farms, situated nearer to the outer margins of the area which possess more low hill ground and a somewhat higher proportion of arable in-bye - a hirsel of Cheviot ewes and a herd of breeding cows may be kept. It is however also worth remembering that wide stretches of these higher moorlands particularly over the southern plateau, provide feeding grounds for grouse as well as for sheep, the management of which, especially in respect of heather burning, is a matter on which shepherds and gamekeepers are not always in complete accord.

Yet another more modern utilisation of the rough moorlands of the Peebles area is represented by the small, but well established, Forestry Commission plantings of Glentress Forest in the south-west. This block of some 2000 acres of coniferous trees was first established in 1903 with the main plantings effected between 1922-1936, together with a nursery and, until very recently, a Forestry Commission School. Over 60% of the species planted comprise larch and Scots pine, better suited to the drier eastern conditions than spruce, which only accounts for some 20% of the trees. Growth is relatively slower than in western areas but the resulting wood is considered of a high quality. On the steep slopes, formerly occupied by heather and/or bracken, the bulk of the plantation is concentrated between 1000' and 1250', although it extends up the deeper sheltered sides of a deep 'hope' to attain a maximum altitude of 1750' on Caresman Hill[1]. At this upper limit however exposure has taken its toll and the forest becomes ragged and open, and the trees small.

Elsewhere, apart from occasional scrubs of oak, birch, rowan or hawthorn on lower valley slopes, these moorlands are bare and treeless. Woodland, usually in the form of coniferous or mixed coniferous and deciduous plantations and shelter belts is confined solely to the zone of improved land below 1250' - or occasionally within the moorland area as protective plantations around farms and lodges along the principal valleys. Two world wars have reduced the original extent to these woodlands - initiated largely in the late 18th and 19th centuries. An interesting isolated relict of a former landlord's energy is seen in George Wood, a small compact rectangular plantation of firs and spruce which survives on the high plateau at 1650' on the interfleuve between the Luggate and Heriot Waters. Now neglected, and with its fences broken, it is open to the in-roads of sheep and is somewhat decimated. It, nevertheless, gives an interesting indication of the heights to which trees can survive - and probably did in the past - in a now virtually treeless terrain.

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1 Map reference /285425.

CHAPTER X

Vegetation of the Peebles Area - Wet Moorlands.

Above the upper limit of woodlands and improved land - over approximately 1250', the Peebles areas is dominated by a rolling expanse of virtually treeless and uninterrupted, unimproved,rough moorland grazings. The vegetation of these present,not only a similarly diverse and complex pattern of species and plant associations,but also,a botanical composition generally closely comparable with that of the Wanlockhead area; further many of the principal plant associations characteristic of this preceeding area are,with largely the same form and composition, repeated here. Here too, the classification of the vegetation into broad associations has been based <u>primarily</u> on their botanical content and the repetition in the Peebles area of thoseprincipal landform features characteristic also of the Wanlockhead area - the plateau-like nature of the upland, considerably dissected but with often a sharp clear cut definition between the alternating very steep valley side slopes, and the gentle sloping facets of varying width across the interfleuves - has resulted in a similar sharpness of distinction between areas of wet and dry moorland - a distinction which has once again facilitated their recognition, classification,and eventual representation on a vegetation map (see F.48). However, while the similarity between their associations is close, their individual extent and the pattern of their distribution provides a considerable indeed, at times, striking contrast between the Wanlockhead and Peebles areas.

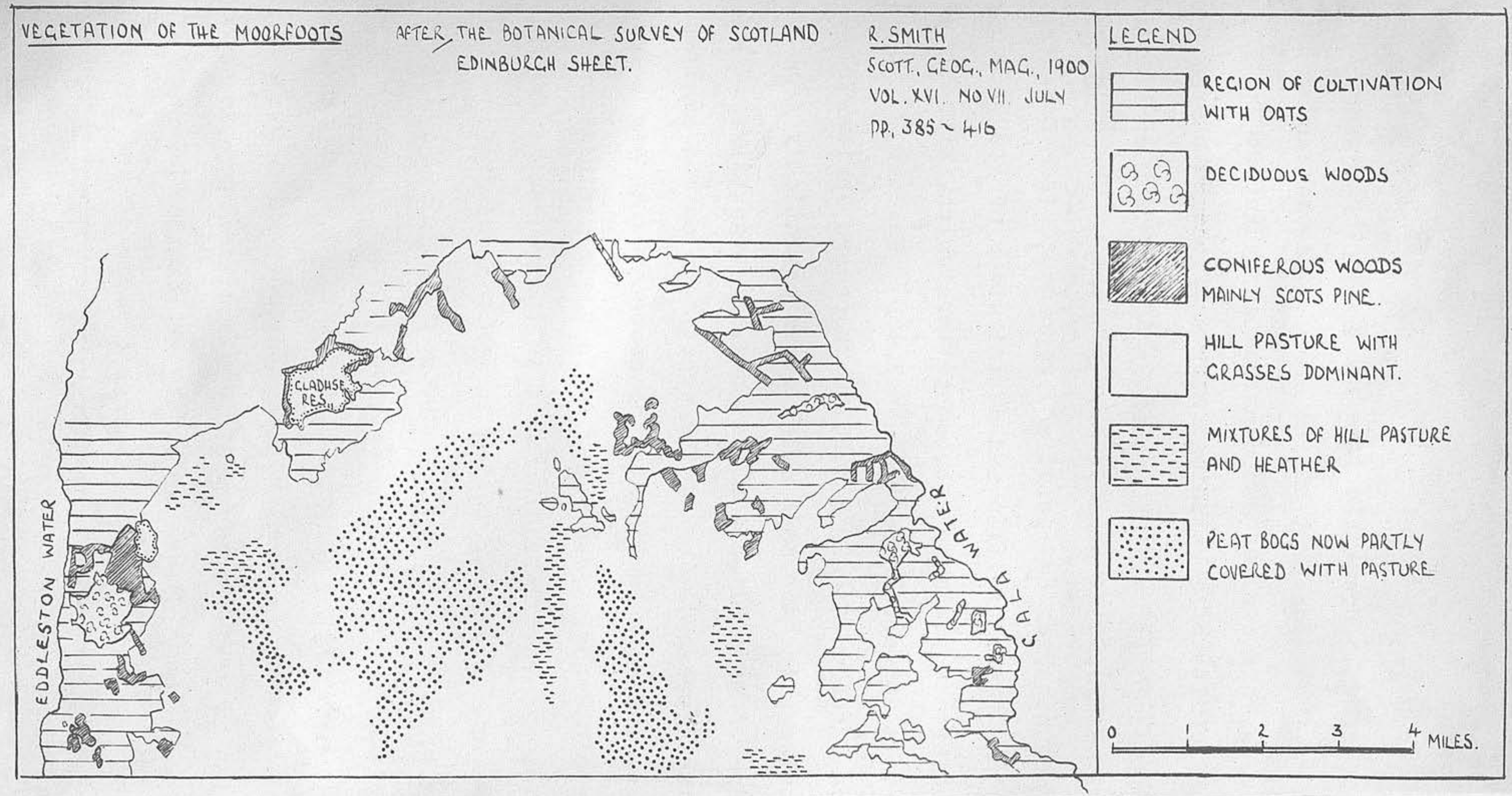
VEGETATION OF THE MOORFOOTS
AFTER THE BOTANICAL SURVEY OF SCOTLAND
EDINBURGH SHEET.
R. SMITH
SCOTT. GEOG., MAG., 1900
VOL. XVI. NO VII. JULY
PP. 385 ~ 416
LEGEND
REGION OF CULTIVATION WITH OATS
DECIDUOUS WOODS
CONIFEROUS WOODS MAINLY SCOTS PINE.
HILL PASTURE WITH GRASSES DOMINANT.
MIXTURES OF HILL PASTURE AND HEATHER
PEAT BOGS NOW PARTLY COVERED WITH PASTURE
0
1
2
3
4
MILES.
GLADHSE RES.
EDDLESTON WATER
GALA WATER

DIAGRAM 6.

The latter area is however unique among the three under consideration in that, for part of its area, a vegetation map already exists. This earlier map, constructed by Robert Smith[1] in 1900 on the results of a botanical survey of the Edinburgh District, incorporates the northern part of the Peebles area - in fact, practically all of the northern plateau. The relevant part of that map has been extracted and reproduced (see Diagram 6. (opposite)). The definition and distribution of its principal moorland associations presents a broad pattern which, with certain modifications, is comparable to that on F.48. However, constructed on a scale of only 1:126,720, there are obvious differences between the two maps which arise essentially from the greater measure of generalisation that had, of necessity, to be employed in the representation of the vegetation on the smaller scale. These, and more fundamental descrepancies in the actual extent of certain associations and also in their definitions as between the two maps, will be discussed in the course of the following analysis of the vegetation in the Peebles area.

Once again, on the basis of plant species typically indicative of wet conditions, and usually associated with an appreciable depth (usually over 9") of acid peat, a distinction has been drawn between wet and dry moorland associations, with, as well, the recognition of certain intermediate associations transitional between the two. Considering first the wet moorlands - which, of one kind or another, must occupy some 45%-50% of the total

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1 Smith, R., (1900) pp. 385-416.

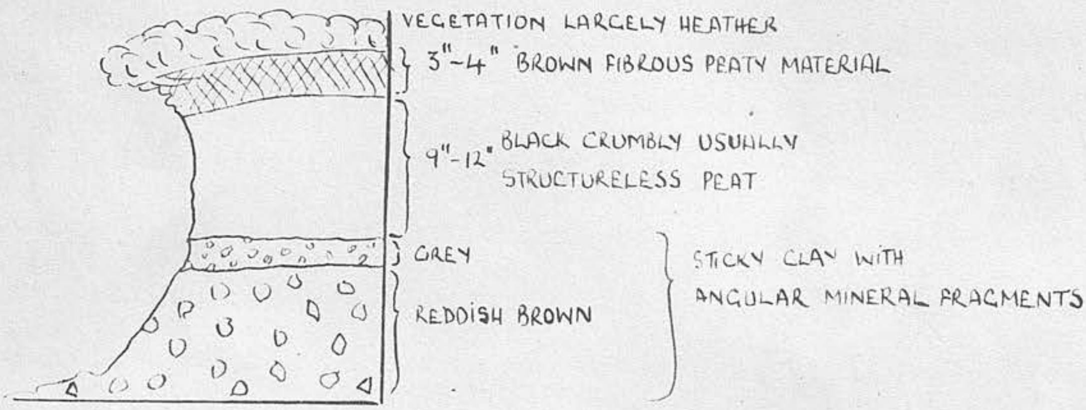
surface of the Peebles area, three principal associations have been mapped which can be defined and distinguished on the basis of their botanical characteristics, of their general colour and appearance, of their relative distribution in relation to landform and of their utilisation by man. They are in order of decreasing altitude:

1. Hagged peat caps often with considerable heather.	either Calluna vulgaris (d) or Scirpus caespitosus) Eriophorum vaginatum) (co-d)	black	usually over 1750'
2. Mixed wet moor	Calluna vulgaris) Scirpus caespitosus) (co-d) Eriophorum vaginatum)	brown	generally 1500'-1750' but also 1500'-1250'.
3. Eriophorum moor	tufted Eriophorum vaginatum (d)	green	1250'-1600' but usually below 1500'

(2. and 3. commonly overlap or interpenetrate each other).

Hagged peat caps with considerable heather, a compendious title for a somewhat mixed and, at times, variable association which is more or less synonymous in its botanical characteristics, its relative position and its distribution with the 'hagged peat' association of the Wanlockhead area but which, as F. 48 indicates, is in the Peebles area not only the most widespread member of the wet moorland, but it covers an altogether greater area than in the former district. It is an association often notable for the amount of heather (Calluna vulgaris) on a frequently thick layer

DIAGRAM 7.



SOIL PROFILE EXPOSED BY PEAT HAGGING

of soft and often wet peat, generally over 9" but rarely in this area, as far as could be ascertained, exceeding 4'-5' in depth (see Diagram 7 (opposite)) and forming what appears to be from a distance, especially in late spring and early summer, a 'black' blanket over the higher, broader, gently-sloping hill and ridge summits. This high cap of peat has been subjected to considerable natural dissection and erosion, and its outer margins particularly, are ragged, broken, and uneven, having been cut into a number of ridges and lobes of varying width by the deep channels or hags which, cutting down to the mineral soil or bed rock below, penetrate in places almost to the heart of the large peat masses (see F. 75 (68)(69)). From its eroded margins large blocks of thick peat have become detached and have slumped down the steeper slopes below (see F. 70 (49)). Hagging is often most pronounced where the head streams of the steeper, usually (though not invariably) south or south-west facing 'cleuchs' and 'hopes' are extending their courses by raw, deep, savagely-eroded gullies (see F. 71 (57)(58)) into the edges, and beyond the margins, of the broader, higher, peat-covered plateaus. The sharply-defined, blackened outline of the eroded peat edges (see F. 70 (48)) serve to indicate, often very clearly, the extent of this association.

The vegetation of which it is composed varies from one locality to another, depending upon the particular degree of erosion and drainage of the underlying peat. A general cross-section suggests the following assemblage of species:-

Calluna vulgaris (f. to d.) usually long, leggy, and frequently completely dominant, particularly near the margins of the peat cap where hagging is most advanced.

Eriophorum angustifolium (f) especially where heather is dominant on a Sphagnum layer, it may be one of its commonest associates. Its relative abundance would appear to be a characteristic feature of this association.

Eriophorum vaginatum and Scirpus caespitosus (f.) → (co-d): often (co-d) on wide areas of unbroken peat especially towards the centre of the cap where there may also be a fairly continuous ground layer of Sphagnum. In such cases heather is negligible in amount and largely replace by -

Erica tetralix (f-a)

Rubus chamaemorus (f-a) most abundant where peat is hagged but may also form wide spreads over unbroken peat with much heather[1].

other species frequently present, in varying amounts include -

Vaccinium myrtillus	(f)	where drier conditions prevail
V. Vitis-idaea	(o. f.)	
Empetrum nigrum	(o. f.)	
Cladonia spp.	(o.)	at high altitudes
Nardus stricta	(o) - (f)	

The whole association in fact, from a botanical stand-point, presents two slightly different aspects under -

a) drier conditions, with

Calluna vulgaris (d)
Empetrum nigrum (f.) sometimes (co-d)
Vaccinium myrtillus (v. f.) may be locally dominant especially in very steep slopes below peat edges and along the sides of pronounced hags.
Eriophorum angustifolium (f) (characteristic)
Rubus chamaemorus (f.-a.) (characteristic)
Cladonia spp. (f.)
Sphagnum (o. f.) very variable).
Scirpus caespitosus) Eriophorum vaginatum) (o.-f.)

b) wetter conditions, with

Eriophorum vaginatum) Scirpus caespitosus) (co-d)
Eriophorum angustifolium(o-f)
Erica tetralix (a)
Sphagnum spp. (f-d)
Rubus chamaemorus(o. f.)
Calluna vulgaris (o.-f.)

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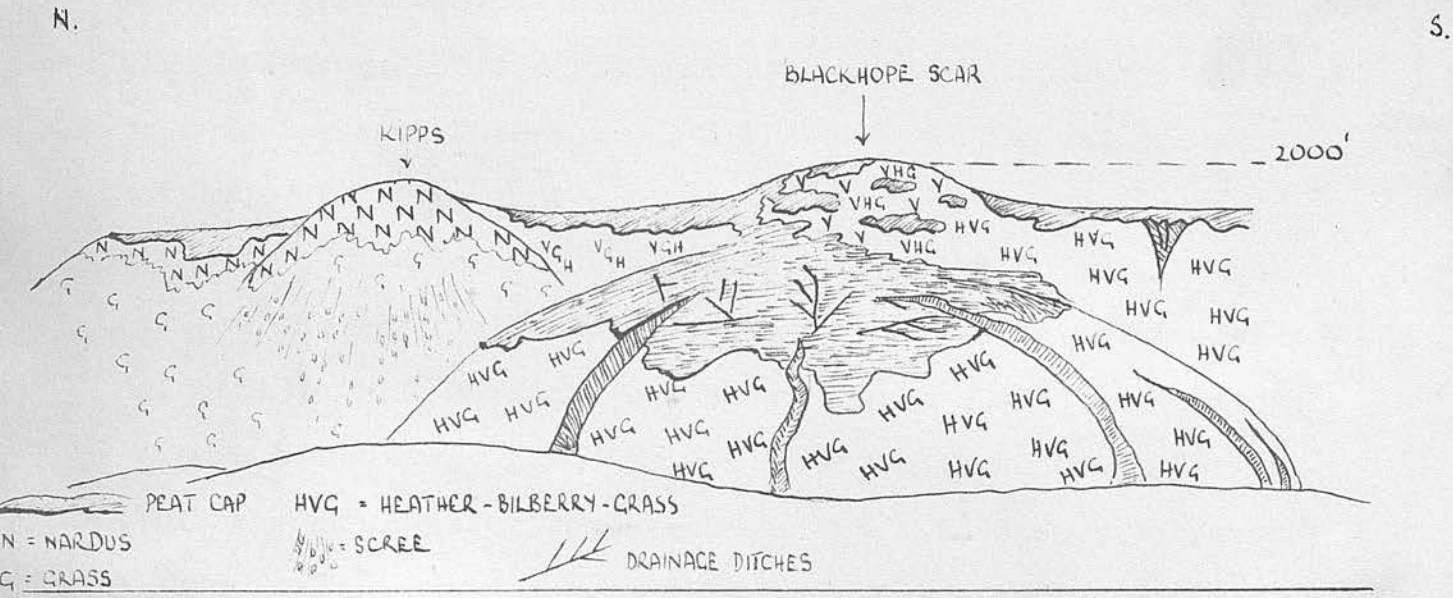
1 See page 146 for notes on its particular significance in the association.

DIAGRAM 8.



PANORAMA OF PART OF N. LEITHEN PLATEAU SEEN FROM LEFT BANK OF NORTH ESK RIVER.

As such, and with conspicuous hagging as its principal and most readily observed characteristic and means of identification, this most extensive of the wet moorland associations completely dominates all areas of gentle slope (usually less than 10°) over 1750'. From the Moorfoot edge above Gladhouse Reservoir it stretches as an almost continuous blanket to the south-east of the area, above Caddon Water - its complete continuity broken only where the North Esk river and the Dewar-Glentress valley have cut deeply across the high plateau. This extensive spread of hagged peat coincides closely with, and indeed must owe its original formation to, the survival of relatively undissected surfaces of gentle slope across the northern part of the high Leithen Plateau (see F. 44 and also F. 42) where broad summit areas, of a general slope usually considerably less than 10°, and often with a nucleus where gradients are of the order of 2° or less (see F. 41), have remained intact between 1750'-2000'. Over many of the low broad swells which, rising to 2000'-2100', project slightly above the general level of the high plateau at 1850'-1750' approximately (see F. 70 (47)), the peat cover is often thin or, as on the west slope of Blackhope Scar (2137')[1], it has been broken up and reduced to a patch-work of isolated mounds of peat, scattered like black flakes down the slightly steeper slopes of this projection (see F. 75 (69) and Diagram 8 (opposite)); or again, in extreme cases, as for instance to the south of Geoffrey's

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[1] Map reference /312485.

Corse (2040')[1], and on the south facing slope of Windlestraw Law (2147'-2162')[2], the peat cover has been completely removed and is replaced by a vegetation resembling that of the summit vegetation of the western areas, and composed generally of a mixture of Festuca ovina, Vaccinium myrtillus, sparse Nardus stricta, Sphagnum spp., and Calluna vulgaris, with occasional patches of Rhacomitrium lanuginosum. Indeed it was almost as though these higher domes had pushed up through the surrounding thick peat cover!

Along the southern and south-western margin of the Leithen plateau (see F. 44 L. 1. 1) - there where the head streams of the Leithen Water and other tributaries of the Tweed farther to the east, have bitten deeply into the high ground and the plateau remnants are everywhere bounded by, usually excessively, steep slopes - the actual margins of the 'hagged peat' association are most clearly and precisely defined (see F. 75 (68)(69)). With few exceptions, it is confined everywhere along the south and south-west of the plateau to altitudes of 1750' and over, and the black eroded edges of the peat serve to outline regularly, and indeed almost geometrically, the edges of the gently sloping plateau summits: below, gradients steepen rapidly and the boundary between the wet association of the peat and the dry moorland which replaces it on the steep slopes below is sharp and clear.

Towards the north and north-east the high Leithen plateau (see F. 44 L. 1) is not so deeply dissected, its limits in this

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[1] Map reference /278499.

[2] Map reference /305430.

direction are less clearly marked and it slopes, gently and gradually, by way of long broad spurs from 1750' down to 1500' approximately. Peat dissection and hagging are not so intense nor so widespread and the boundaries of the association are consequently much less clearly marked (see F.75 (69): F.76 (71)). The 'hagged peat' association may lap down valley side slopes and lower ridge summits to 1500', but usually, below 1750'-1700' it is replaced gradually, indeed imperceptibly, by

<u>Mixed Wet Moor.</u> There is rarely any physical break between this and the preceeding association and the mixed wet moor association indicated on F.48 is so closely related to the 'hagged peat' and, at times, so difficult to distinguish from it, that it was only after some consideration that it was finally decided to recognise it as a separate association[1] on the basis of the <u>four</u> aspects in which it differs most clearly from the 'hagged peat', and which are -

1) It is usually associated with a somewhat thinner peat layer, rarely over 2' and often less, but it can nevertheless on occasions be wetter than some of the "hagged peat" areas.

2) While heather is always present, though in varying proportions, it rarely attains the same degree of dominance that it can, and does, under certain circumstances on 'hagged peat' - and the mixed wet moor association is typically composed of a more even mixture

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[1] The mixed wet moor association is analogous to that defined for the Wanlockhead area, see p143 but the difficulty of its classification did not arise there to the same extent, since it represents there the major wet moorland association and areas of hagged peat are very small and much drier than in the Peebles area.

of Calluna, Scirpus and Eriophorum.

3) Its vegetation exhibits, not uniformily nor persistently but nevertheless frequently, a tendency to assume a tussocky habit.

On the basis of its botanical composition the recognition and justification of mixed wet moor as a separate and distinct association must be an extremely arbitary decision. Not only is it of a variable and mixed content, ranging across sites which are very wet to those which are nearly dry, but sharing, as it does, most of its species and sometimes in the same proportions, with the hagged peat association, it is rarely easy to define precisely and exactly, or yet to draw accurately the boundary between it and the higher peat caps. In its most typical and characteristic form and composition - that in which it differs most clearly from the preceding association - it consists of a diffuse mixture of three co-dominants -

Calluna vulgaris
Eriophorum vaginatum
Scirpus caespitosus

usually of a short (ankle deep), even growth - though occasionally one, or all three together, of these species may be slightly tufted in form (see F. 70 (50)). However, over a relatively small range of space, this association may vary widely and rapidly from this typical form. In some instances Calluna vulgaris may become almost completely dominant. Of the latter two species, Eriophorum vaginatum and Scirpus caespitosus, which vary in amount from place to place, one or other may be co-dominant with Calluna alone.

These three most usual co-dominants are also commonly accompanied by a variety of species including -

Eriophorum angustifolium	(o.)..	though seldom as frequent or as abundant as in "hagged peat".
Sphagnum spp.,	(f.)..	varies; often patchy and discontinuous, sometimes widespread in ground layer.
Vaccinium myrtillus	(f.)..	at times co-dominant with Calluna especially when the association has a tussocky form.
Empetrum nigrum	(o. f.)	
Polytrichum commune	(f.)..	especially where association becomes markedly tufted.
Molinia caerulea	(o.-f.)..	rarely abundant but is a <u>characteristic</u> species sometimes evenly scattered through the association but occurring most frequently at the outer margins of the association.
Nardus stricta	(f.)..	especially towards the outer margins of the association where it frequently attains local co-dominance with Molinia caerulea. Also occurs in patches of varying width on drier sites within the association.
Juncus articulatus	(l. a.)..	
Aira flexuosa	(o.)..	
Rubus chamaemorus	(o.)..	usually on higher parts of the association but neither so frequent nor so characteristic as in the former association.

The final 4), and what is here considered the most important, difference between the two associations classified as mixed wet moor and hagged peat is that the former has everywhere throughout its extent been subjected to considerable modification arising from man's use of it in one way or another, and in particular by:

a) <u>Artificial drainage</u>: the whole of the area indicated on the vegetation map as mixed wet moor bears evidence of artificial drainage at one time or another, being liberally slashed by a geometrical pattern of drainage ditches, in varying stages of upkeep (see F. 70(52):F.75(69):F. 76(70), (71):F. 77(72)). Some have become choked with Sphagnum or dead Molinia; others, particularly where cut down, or even obliquely across, relatively steeply inclined slopes have been over deepened (1'-3') and widened by accelerated run-off and erosion, so that the channels now bite deeply into the mineral soil below. To no small extent the variations of wetness and dryness appear to be related to the present efficacy of this artificial drainage system. In contrast, nowhere, as far as could be ascertained, has artificial drainage been so extensively effected within the "hagged peat" area.

b) Cutting: very frequently the mixed wet moor areas bear the scars of peat cutting for fuel which, though still practised, was undoubtedly more prevalent in the past. Over wide areas rectangular depressions (see F. 70 (51), (54)) may be floored with a thick spongy layer of Sphagnum, with only the intervening ridges remaining some 6" to 1' above the general level of the ground and carrying a drier vegetation. No evidences of cutting were seen on the "hagged peat" areas.

c) Burning: Moor burning is a frequent and widespread practice over all areas of mixed wet moor, often carried out on a short rotation, since on the moister peat areas heather is generally acknowledged to return more rapidly than on the dry 'hard' ground of the typical heather moorlands[1]. The variability of the heather content may probably arise from this practice, a practise

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1 Smith, W.G., (1918b) p. 266.

which often imposes on this wet moorland association the patchwork pattern most usually associated with the dry heather moorland (see F. 70 (53)). It has, no doubt, also contributed to the overwhelming dominance of heather in many places, a dominance which brings it very close in appearance to hagged peat and effectively obscures any boundary which may exist between the two (see F. 75(69), (70)). While not unknown on the high plateau, burning is not there so widespread nor so regular a practice.

d) Grazing: The mixed wet moor, occurring as it does at relatively lower altitudes, and with its valuable mixture of species, is subjected to fairly continual and regular sheep grazing throughout the year, and particularly in spring and early summer when Eriophorum vaginatum and other species provide a nutritous early bite for ewes and lambs. The hagged peat of the high plateau over 1750' is also grazed by sheep but, with its harsher climatic conditions and considerable exposure, for a relatively shorter period. It has been suggested by many shepherds that these higher and more exposed parts of the plateau are never or rarely used by sheep in the winter months.

It would appear reasonable to assume, therefore, that not only the rapid and often extreme variations in the content and form displayed within the mixed wet moor, but also the several, albeit slight, differences which exist between it and the hagged peat areas are a direct result of the more intensive use that has been made of such wet moorland areas. It was therefore finally decided, on the basis of these striking and widespread modifications, to recognise the mixed wet moor as a separate and distinct association. However, because of the virtual impossibility of defining its extent and boundaries in the field, it was further decided to deduce its limits, and particularly its upper limits, from aerial photographs and to classify and represent as mixed wet moor only those areas where artificial drainage (whose pattern is usually clearly visible on such photos -see F.77(72)) had been effected. The limits indicated by this means on the aerial photographs agreed very closely to those which had been generally suspected and deduced from the results of field work.

The mixed wet moor association, thus defined and delimited on the vegetation map (see F.48), forms a narrow, uneven fringe around the northern, north-western and, to a limited extent, western margins of the centrally placed hagged peat cap and over the lower parts of the high plateau at between approximately 1700'-1500' - its extent dependent upon the development of areas of gentle slope at these altitudes. In the introductory analysis of the physical features of the Peebles area the high Leithen plateau was defined as that central area over which surface levels attained a general accordance of between 1850'-1750' and a gradual slope to 1500' in both north-east and south-west directions. It was further indicated that only in the north-east and east do relatively broad undissected summit areas of gentle slope survive at these altitudes. There are also, over this area of high plateau between 1750'+ - 1500', indications of an intermediate level, at between 1600' - 1500', between the high plateau and the lower surface at 1250', which is separated from the higher plateau by slightly steeper slopes between 1650'-1700'. This break of slope is most clearly developed above the North Esk valley where the 1600' - 1500' level is represented as a well marked bench (see F. 76(71)) - and again below Ladyside Heights[1]. It nowhere, however, coincides with a break in the continuity of the wet moorland vegetation and in these areas hagged peat grades gradually into mixed wet moor (see F. 76(70) (71):F. 77(72):F. 78(73)). Nevertheless, it is over those areas of gentle slope between 1500'-1700', occurring either as valley side benches or, in the north-east particularly, across the lower summits of the broad spurs which project in that direction from the high central plateau, that the mixed moor is most generally located. This association is however continued to even lower levels, down to 1250' in the extreme north-east of the area, where relatively broad, but feebly dissected, surfaces of gentle slope have not been cultivated. At such altitudes it very often alternates or interpenetrates with the succeeding association - Eriophorum moor.

Representing, as it seems to do, the more highly modified margins of the hagged peat area, there is every reason to suspect that the mixed wet moor association has been derived directly from the hagged peat vegetation (the latter being, no doubt, the partially desiccated and eroded remains of the original

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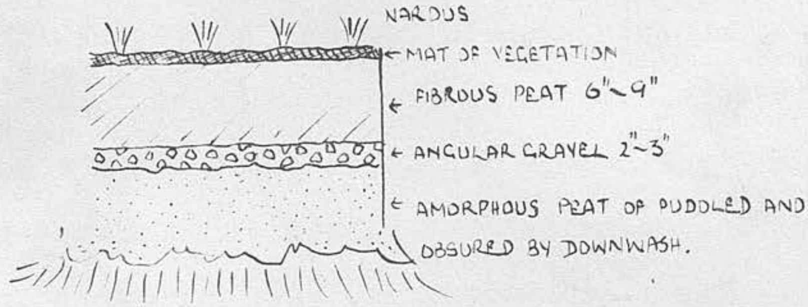
1 Map reference /357472.

DIAGRAM 9.

SOIL SECTION (LADYSIDE BURN 1500' APPROX.)



blanket-bog which established itself on these high gently sloping surfaces) at those lower altitudes which, more accessible to man and his animals, have thereby been more vigorously and intensively attacked. However, as was noted under similar circumstances in the preceding section[1], the fact cannot be overlooked, that many of these lower areas carrying mixed wet moor, particularly where they lie below a slightly steeper slope must have been, and still be, subjected to and influenced by the downwash of peat eroded from higher levels above. Some, or indeed all, of this association may have established itself on re-distributed peat and not necessarily be derived from a vegetation growing on a peat cover formed in situ[2]. An interesting and also enlightening suggestion of the natural modifications and vicissitudes that such areas may have undergone in the past is revealed in a soil profile (see diagram 9 (opposite)) exposed at the edge of the high Leithen plateau, at about 1500' at the head of Ladyside Burn, where a distinct layer of angular gravel, intercalated between two distinct peaty layers, bears witness to a formerly intense, rapid erosion and downwash of mineral soil[3].

While, as has been indicated, mixed wet moor may be continuous over areas of gentle slope down to 1250', at these lower altitudes and around its lower and outer margins the association, however, frequently becomes conspicuously and indeed, at times, excessively

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1 See Section III p. 151

2 Fenton, E.W., (1952) p. 50 et seq.

3 Similar features have also been observed in parts of South-East Scotland by Fenton, E.W. (1952) p. 38.

tussocky and Eriophorum vaginatum, often forming the nuclei of the tussocks, begins to assume a more dominant role. Finally, in certain localities mixed wet moor may be replaced by an association completely dominated by Eriophorum vaginatum and containing little or no heather -

Eriophorum moor reveals in its most typical form the following composition -

Eriophorum vaginatum	(d)	in large tussocks and dominant often to the exclusion of other species.
Aira flexuosa Vaccinium myrtillus Molinia caerulea	)	are frequently present, though in smaller quantities, in tussocks of matted vegetation which have formed around the core of Eriophorum vaginatum.

In some cases the tussocks are closely spaced and form a continuous canopy, in others, and generally under drier conditions, they are more widely spaced and Polytrichum commune and, to a lesser extent, Sphagnum spp. are frequently abundant in the ground layer, the dominance of one or other of these mosses depending on local drainage conditions (see F. 72 (59), (60) (61)). Other species commonly associated with the tufted Eriophorum moor include -

Nardus stricta	(f.)
Erica tetralix Scirpus caespitosus	) frequently present, though only) conspicuous under wetter conditions.
Calluna vulgaris	(only v. o.)

In its composition and form Eriophorum moor is more or less analagous to the association of the same name in the Wanlockhead area[1], although, in its purest and most tufted form in the Peebles area, it appears to occupy a somewhat drier habitat and to be more

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1 See Section III p.152

frequently accompanied by abundant Polytrichum commune than by Sphagnum. Nevertheless, its relationship to the preceding and adjacent mixed wet moor in the Peebles area must be considered in the light of the same factors as in the Wanlockhead area[1].

As before, it probably owes its dominance either to the influence of acid peat downwashed from areas above it, or, to an even more advanced modification of peat conditions by burning, which may have destroyed the heather, and by draining at the lower outer margins of the mixed wet moor. With its drier site conditions and relative abundance of Polytrichum commune it is difficult to think otherwise than that it represents a 'degraded' form of this preceding association.

Eriophorum moor as a pure association, however, is rarely extensive or widespread. It occurs either as a narrow marginal fringe to the mixed wet moor, with its continuity often interrupted by intervening patches of Nardus stricta, or as a 'facies' frequently becoming locally dominant among areas otherwise covered with the more mixed association. In either instance, it would be extremely difficult to delimit an exact boundary between these two contiguous and closely related associations. The vegetation map (see F.48) attempts to do no more than merely indicate its position relative to mixed wet moor over those localities where it was found to be most highly developed.

Bearing in mind its principal characteristics, the vegetation map reveals that it does occur over 1500' but, at

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1 See Section III p.154-156

such altitudes, mainly to the north-west of the area and along the outer margins of those wide, gently sloping areas of plateau remnants between 1500'-1700', so well developed above the Moorfoot scarp (see F. 77(72)); indeed, at times, this fringe is barely extensive enough to warrant its recognition on a vegetation map of this particular scale. It is, however, more widely developed over gently sloping areas below 1500' (see F. 78 (73)) - between 1500' - 1250'/1200' - and its distribution coincides with such areas in the north-east of the district which, above the Heriot and Blackhope valleys, represent the inner, slightly higher and relatively poorly dissected parts of that lower surface developed within the Gala-Caddon physical region. (see F. 44) This represents an area whose width, generally gentle gradients and consequent lack of drainage have defied cultivation but which, at relatively low altitudes and in close proximity to the improved land and farm steadings, has probably suffered even more drastic modification from the effects of draining etc. than the higher areas of mixed wet moor. It is worth noting, however, that over the wider of these plateau remnants at 1250', where presumably the peat is thicker and the moisture content higher much heather is often present and the vegetation is rather one of mixed wet moor in which Eriophorum becomes conspicuously dominant and strongly tufted.

What then is the significance and status of these three associations and how far is it justifiable to separate them for representation on the vegetation map?

These three wet moorland associations - hagged peat ", mixed wet moor and Eriophorum moor - are closely related in, there is every reason to believe, much the same manner as in the Wanlockhead area. They probably represent 'facies' of the one continuous cover of blanket-bog initiated over these gently sloping surfaces at high altitudes in the east of Scotland during the wetter climates of the Atlantic or Sub-Atlantic phases[1,2] and which, since then, has undergone varying degrees of modification - modifications resulting as much from progressive natural erosion and drainage consequent upon the continual headward erosion of burns, gullies etc. and continuous utilisation by man, as from changes in climate in modern times. But there is no guarantee that this has in fact been the origin of the whole of the peat covered area. However, what ever the origin of the original peat and the factors responsible for its modification - three stages in its 'degeneration', similar to those suggested for the Wanlockhead area[3], from PEAT BOG → MIXED MOOR → COTTON SEDGE or HEATHER MOOR are represented in concentric zones, of varying width and continuity, away from the present centre of the peat mass (or masses) and at successively lower levels.

The general correlation which exists to-day between these three principal associations and those various summit levels

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1 Pearsall, (1950) pp. 201-205.

2 Tansley, A.G., (1949b) p. 12 and pp. 719-20.

3 See Section III p. 155

where wide areas of gentle slope still remain,

i.e. (1.) High plateau 2000'-1750' - hagged peat.
(2.) Intermediate plateau 1700'-1500' - mixed wet moor.
(3.) Low plateau 1500'-1250' mixed wet moor and/or Eriophorum moor.

is a result, it would appear, primarily of the greater accessibility of the lower levels to man and, also, to the fact that these must be successively influenced by downwash of peat from the higher levels above. Indeed, there would be, on the basis of their close botanical relationship, and on the fact that they are often linked by the one continuous layer of peat, every justification for classifying them all together under, what Pearsall has called, mixed moor,[1] the minutiae and variations of whose composition has been analysed in such detail throughout many parts of South East Scotland by Fenton[2].

As formerly intimated[3], a certain correlation exists between the distribution of wet moorland on the Vegetation map of the Peebles area (see F. 48) and that indicated as 'peat bogs now partly covered with pasture' on Robert Smith's early vegetation map (see Diagram 6 - opposite page 202). Certainly the pattern is generally the same but, except on the Moorfoot plateau, the actual extent and the outer limits of the margin on the latter map rarely coincide closely with those on F. 48. Indeed there would appear to be a much closer correlation with Smith's peat bog areas and the areas of peat as mapped by the Geological

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1 See Section III p.149

2 Fenton, E. W., (1951a) particularly p. 45 and (1952) particularly pp. 50-59.

3 See p.202

Survey (see F. 43). His map does not incorporate, what has been indicated as, the modified marginal zones of mixed wet and Eriophorum moors. Further, it is not altogether easy to appreciate exactly what is implied by the title "peat bogs now partly covered with pasture". The literal interpretation, in the light of what Smith classes as hill pasture, is hardly the case for most of the area he indicates as peat bogs. Certainly, on the margins of the wet moorland areas, or on the occasional steep slopes which break its continuity, as for instance along the south facing slope of the Moorfoots between 1500'-1250', or on those dome-like areas over 2000' where the peat layer is thin or absent - a grassy vegetation generally dominated by Nardus stricta has established itself but hardly frequently enough throughout the main bulk of the wet moorlands to justify what is here considered a somewhat drastic and over sweeping generalisation[1]. Further, one is seriously handicapped in the interpretation of Smith's map by the fact that the association so called 'peat bogs now partly covered with pasture' is <u>never</u> specifically defined.

However, in his discussion of heather dominated associations[2] he outlines three associations, whose main features, as indicated by him, are summarised below, two of which would be more applicable to the peat areas under consideration.

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1 Although 54 years have elapsed since Smith made his survey, and changes in the vegetation must undoubtedly have taken place, it is considered very unlikely that they could have effectively altered such a widespread area.

2 Smith, R., (1900) pp. 403-406.

1) Heather (Calluna vulgaris) on thin dry soils - the equivalent of the German 'Heide' or English Heath (a correlation not generally accepted now) which corresponds to the dry heather moorland of the present survey.

2) Calluna on a moister habitat; on ground less steeply inclined; peaty component more abundant and largely formed originally of Sphagnum; species such as Erica tetralix, Empetrum nigrum, Scirpus caespitosus and Juncus squarrosus, indicative of wetter conditions among an assemblage of heather and other dry plants; called heather moor (Heidemoor).

3) 'Sphagnum moor' or 'moss moor'; moister still and with more peat; association containing Calluna vulgaris, Eriophorum vaginatum, Sphagnum, Erica tetralix, Empetrum nigrum, Scirpus caespitosus, Molinia caerulea, Schollera oxycoccus, Drosera rotundifolia.

The last of these associations appears to coincide with what he regards as 'peat bogs', purely and simply, and which as such does not occur within the upland area under consideration, but is reserved for such essentially lowland 'mosses' as Fala Moor, Cobinshaw, and Auchencorth Moss. Yet in this writer's opinion the areas in the Moorfoots classed as 'peat bogs with much pasture' would approximate more closely to either his Sphagnum - moor (3) or Calluna on a moister habitat (2). To a very marked extent (2) and (3) can be correlated with mixed wet moor and hagged peat areas on the vegetation map F. 48. However, Smith was faced the same problem that must confront every mapper of vegetation - how to classify reasonably areas of relatively deep peat carrying a wet, but very mixed assemblage of species, and which has undergone varying degrees of modification from one cause or another. It is a problem which his brother William Smith approached in a more realistic fashion at a later date, when he suggested[1] that peat carrying a mixed herbage could from a grazing point of view be classed into -

a) Unbroken peat with little heather - Eriophorum and Scirpus often co-dominant.
b) Peat broken by hags carrying more heather.
c) A marginal zone around the peat which carries either Moor Mat Grass (Nardus stricta) or Molinia. -

a classification which, in a somewhat modified form, - i.e. in that (a) and (b) have been grouped together under 'hagged peat' areas and an extra zone of mixed, man-modified wet moor - mixed wet and Eriophorum moor has been added between (b) and (c) - has been adopted in the present survey. Enough, however, has probably been said to indicate the many problems involved in the classification of wet moorland areas and, above all, the necessity that exists for as clear as possible a definition of the basis of such classifications to be made, if any degree of correlation or comparison is to be attained between similar or widely separated areas investigated by individual workers, at the same or different times.

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[1] Smith, W.G., (1918b) pp. 261-269.

CHAPTER XI

Vegetation of the Peebles Area (contd.) -

Intermediate and Dry Moorlands.

Intermediate between the areas of deep wet peat (the thick or 'deep' ground of the sheep farmer) and the 'hard' dry land of the more typical dry moorlands is a marginal zone which, as Smith indicated[1], may carry either Molinia caerulea or Nardus stricta. In the Peebles area Nardus replaces the Molinia of the Wanlockhead area as the dominant and typical species of this zone and becomes - though to a less marked degree than in the case of Molinia - what might be called the 'common denominator' to both wet and dry moorlands.

Nardus shares with Molinia certain characteristics of form, habitat requirements and distribution; commonly strongly tufted in its most vigorous growth form, it occurs similarly over a wide variety of physical habitats and of soils of varying character, but particularly - though not always - on peat or peaty soils, damp but not permanently wet[2 3]. It is however not so tolerant of excessive moisture conditions as Molinia and is not found on deep, wet peat nor over such a <u>wide</u> range of soil conditions, being confined to poor leached and above all acid media - generally possessing a pH value of the order of 3.5[4] and, as Fenton points

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1 See p. 223.

2 Tansley, A.G., (1949a) pp. 514-518.

3 Thomas, B., and Dougall, H.W., (1939a) pp. 172-175.

4 Gimmingham, C.H., (1944) p. 20.

out, "if transplanted to highly cultivated soil (pH7) it tends to die out within a year".[1] Also, it flourishes over a wider altitudinal range; Molinia is frequently limited to below 1500', while Nardus often persists up to, and over, 2000' - and may attain its most striking dominance at altitudes over 1500'. According to Pearsall[2], it is a most prominent species in upland areas within a 'middle zone' above the bracken limit at 1000' and below the montane zone at 2000'. As an individual species Nardus stricta is certainly ubiquitous in the Peebles area within such a comparable zone - above the bracken limit of 1000'/1250', often extending up to 2000', but more frequently confined to a maximum upper limit at 1750' by the extensive peat caps above. Over considerable areas within this zone it assumes a dominance and extent which justifies the recognition and representation of a well marked association,

<u>Nardus moor</u>, with the following general characteristics:

Nardus stricta (d) strongly tufted and often dominant to the virtual exclusion of all other species (see F.71(55):(56)).
or Nardus stricta (d) strongly tufted but accompanied by a number of species including -

Vaccinium myrtillus	(a)	sometimes (co-d) with Nardus.
Juncus squarrosus	(f.a.)	
Aira flexuosa	(o.-f.)	
Calluna vulgaris	(v.o.)	
Galium saxatile	(f)	
Potentilla erecta	(f)	
Anthoxanthum odoratum	(f)	
Hypnum scheberi	(f)	
Polytrichum commune	(f)	often (a.)

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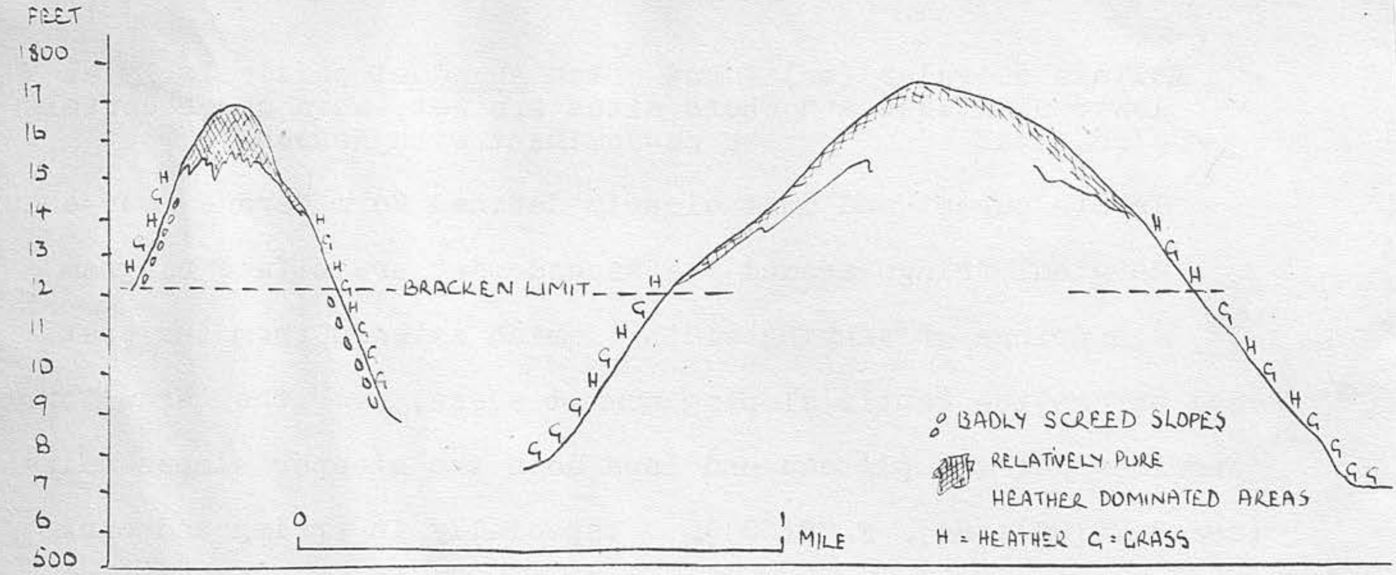
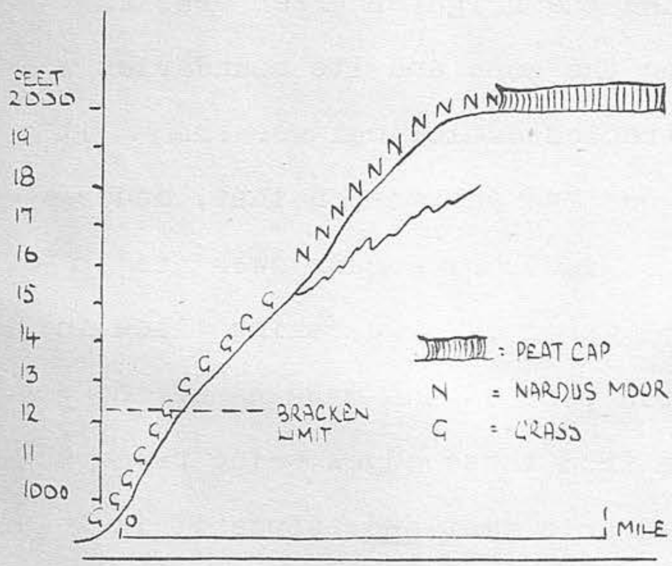
1 Fenton, E.W., (1951a) p.44.

2 Pearsall, W.H., (1950) pp. 104-105.

DIAGRAM 10.

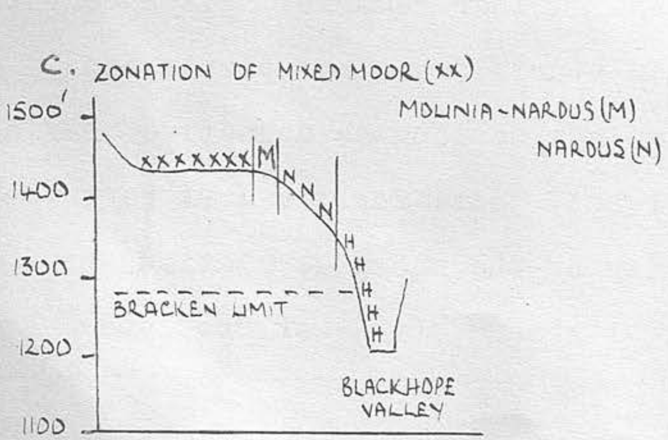


A. VARIATIONS IN HEATHER MOORLAND ASSOCIATIONS ON NARROW STEEP RIDGES OF S. LEITHEN PLATEAU



B. POSITION OF NARDUS ZONE ON TOTTO HILL

C. ZONATION OF MIXED MOOR (xx)



Molinia caerulea (o.) - but often abundant particularly at lower altitudes and where sites are wet, when under certain circumstances it may be co-dominant with Nardus.

In its purest and most clearly defined form Nardus moor occurs as a marginal fringe around the hagged peat areas (see Diagram 10b) - a fringe of varying width - which extends from the peat edge across the gently sloping summit areas, over the 'brow' or 'shoulder' of the plateau and laps down the steeper slopes below (see F.72(63):(64). F.75(68)). Especially in spring and early summer the bleached tufts of Nardus stand out in striking contrast to the black peat edges above and the brighter green bracken and grass slopes below, defining the zone and its boundaries with a vivid clarity which early attracted ecological workers. It was noted by Smith[1] to whom we owe the suggestion that, under such circumstances and in such a position, Nardus owes its dominance to the chemical and physical changes taking place in the decomposing and redistributed peat at the margins of the peat hags, with its spread down slope from these edges being favoured by the downwash of this modified acid peat and, since it is seldom grazed except in early spring by sheep, by selective grazing. Fenton corroborates this view and further remarks, "given certain favourable conditions and a good start, few other plants can compete with Nardus in hill grazings so long as selective grazing continues. It is also significant, that, for the most part the density of Nardus and the density of the sheep population are closely related in the South East area"[2], (i.e. of Scotland).

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[1] Smith, W.G., (1918a) pp. 1-13.

[2] Fenton, E.W., (1936a) pp. 143-152.

Added to these particular soil, and biotic factors, favouring its establishment and dominance in this marginal zone - slope conditions must to a certain extent influence if not determine, the width and extent of the zone[1]. Optimum conditions for the retention of a certain depth of peat, together with a certain degree of moisture, are realised on, either the gently sloping plateau-like areas where deep peat has been removed or its composition modified, or on the 'intermediate' slopes between the flatter summits and the more excessively steep slopes below, where run-off is rapid,and peat and moisture accumulation probably at a minimum or negligible. For instance,the Nardus zone is extraordinarily clearly developed along the southern, south-western and north-western margins of the Leithen plateau (see F. 44) where a fringe of varying width is usually confined to altitudes between 1500'-1750' and though it may under certain circumstances creep up to 2000', rarely extends below 1500'.

The high, bounding, south , south-west, and north-west-facing, intensely dissected margins of the central plateau exhibit, below 1500', often excessively steep slopes. In some cases, indeed where the peat hags give way <u>abruptly</u> to very steep slopes below, and where often there is evidence of burning having aggravated excessive slope and peat erosion, the Nardus zone may be and often is replaced by one in which Vaccinium myrtillus is completely dominant.

On the north-east and east of the Leithen plateau region

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[1] Tansley, A.G., (1949b) p. 172.

Nardus also succeeds, and fringes at lower altitudes, those modified peat areas carrying either mixed wet or Eriophorum moor (see F.70(52): F.77(72): F.78(73)). In this direction it is more widespread and less restricted by slope conditions than to the south of the plateau, and often caps completely the lower parts of spurs, ridges, and wide, gently sloping areas between 1500'-1200'. This is particularly noticeable to the north-east and to the east where the higher parts of those spurs which slope gently from 1500' - 1250'/1000', eastwards from the Caddon and Luggate Waters towards the Gala valley, have not been cultivated or improved. Over relatively gentle slopes that may once have carried a thicker peat cover and a wetter vegetation, Nardus is often completely dominant on a peaty soil - only replaced by grass-heather-bracken on the steep, valley-side slopes of the small youthfull burns which separate these spurs. These are essentially areas which form part of, and often lie directly adjacent to the cultivated and improved land of, the marginally placed semi-arable farms. Their lower altitude and their contiguity to the arable part of the farm, has probably resulted in a fairly high and continuous sheep stocking in comparison to the higher and more exposed ground. Many such Nardus areas, not in direct contact with eroding peat, probably owe their present dominance by this species as much to heavy selective grazing as to any other factor. It should further be emphasised that it is areas such as these, at low altitudes 1500' → 1000' (and particularly between 1250'→1000'), and accessible to improved land and farm steadings, that possess considerable potentialities for improvement,especially where Nardus is rampant, by means of a more mixed and less drastically selective type of grazing[1]. Such potentialities may well be realised if the increasing tendency since the last war for many of these large semi-arable stock rearing farms to run cattle on the hill in the summer months is maintained.

Finally a 'rider' may be added to this discussion of the Nardus moor in the Peebles area. It is worthy of note as, perhaps, a corroboration of the not altogether unimportant part slope conditions may play in determining or influencing the dominance and vigour of Nardus growth. Frequently at the margins of the mixed wet moor association, an intermediate zone between the wet mixed moor without Nardus and the Nardus dominant fringe below may often be observed, where, on slopes, and under moisture conditions intermediate between these two, Molinia caerulea attains a local dominance usually accompanied by or even co-dominant with Nardus stricta (see Diagram 10c opposite p.226). However, it is rarely wide or extensive enough to be mapped, but it is tempting to regard it asyet another link in that succession from peat bog to dry moorland - a succession dependent upon a complex of factors, involving decreasing wetness, increasing slope, and increasing peat decomposition - the developmental stages of which are represented in space in the Peebles area by the following

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1 Grazing value of Nardus would also be improved if it were more regularly burnt - as it used to be in the past, see Fenton, E.W., (1953) p. 152.

sequence:-

HAGGED PEAT
(MIXED WET MOOR)
(ERIOPHORUM MOOR)
MOLINIA-NARDUS ZONE)
NARDUS MOOR

and finally GRASS, HEATHER, and BRACKEN of the true dry moorlands on the steepest and driest slopes. Nardus stricta, however, does occur frequently throughout the dry moorland areas and may attain local dominance or co-dominance within them, but in this respect, it is best treated with, and as part of, such associations and as distinct from the Nardus dominated moor on peaty soils of some depth and moisture which must here be considered as an essentially Intermediate Association forming the link between the Wet and Dry moorlands.

Dry Moorland. The associations into which the dry moorland areas, indicated on the vegetation map (F. 48), have been grouped correspond fairly closely to Smith's original classifications[1] of:-

1. Grass association, or hill pastures of the Silurian hills; Grasses well developed, heather and its associates scarce or absent; association varies with nature of soil, amount of moisture, exposure etc.; occupies a position midway between Nardus or Molinia and heather on lower, drier slopes; heather dominated patches may occur within it.
2. Heather Moorlands (Heath), on poor thin soils; prevalent species include Calluna erica (vulgaris), Erica cinerea, Potentilla silvestris, Galium saxatile, Vaccinium myrtillus,

1 Smith, R., (1900) pp. 463-413.

Agrostis vulgaris, Lathyrus montana, Lotus corniculatus, Deschampsia flexuosa, Galium veris, Pteris aquilinum - together with isolated individuals of other species.

3. Mixture of pasture and heather, developed on wet soils intermediate in character between poor soils of heather moorland and rich soils of better pasture - for instance on northern hill slopes, boulder clay, old peat bogs.

However he was, one feels, inclined to regard these too much as distinct unrelated associations and to correlate them to rigidly with general soil conditions, while of the part biotic factors have played in their establishment or development he says,"the regular grazing, manuring and treading of sheep tend to promote the growth of grasses, whilst on the other hand the regular burning of heather on certain soils strengthens that species. Thus the natural relationships of the species towards each other tend to be altered. Sometimes the changes induced are considerable but as a rule they seem rather to be in the direction of emphasising the original contrast between the two associations: for it is the naturally good pasture which tends to be improved and the natural heather area which is chosen as a grouse preserve"[1] While this can hardly be regarded as a satisfactory explanation of the relationship between the two associations (grass v. heather), or of the dominance of one or another over much of the uplands of the Peebles area, his map (see Diagram 6 opposite p.202.) indicates, as does (F.48), that the 'white' land of the grass

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1 Smith, R., (1900) p.412.

moorland or 'hill pasture' is more prevalent in the northern half of the Peebles area, while the south (not shown on Smith's map) is the domain of more widespread and continuous heather moorland.

Dry Heather Moorland is, on the whole, more widespread and more fully developed than its counterpart in the Wanlockhead area. Climatically the Peebles area provides ideal conditions, given freely drained slopes, for the development of dry heather moorland[1] which Pearsall says, covers areas, "generally those of pronounced slope, and as a general rule the annual rainfall is moderate, commonly between 35"-45", probably always permitting a definite period of soil drying in summer...."[2]

Its specific characteristics are, however, generally similar to those of the preceding area; it is an association, in its purest form, dominated practically exclusively by Calluna vulgaris of a short even growth; it occurs on well drained, 'hard' land of usually a relatively steep slope and with a thin dry but continuous cover of peat or peaty soil 5"-6", or often less, in depth which may overlie a variable depth of mineral soil. As such, it is similarly a 'biotic climax', with its purity and uniformity dependent upon the maintenance of a delicately balanced equilibrium between the interaction of physical and biotic factors - with moor-burning as probably the most important of the latter factors, a practise which has once again imposed on the association the patch work pattern of strips of heather of

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[1] Cf. Tansley, A.G., (1949a) pp. 753-7.

[2] Pearsall, W.H., (1950) p. 143.

varying ages. (See F.69(41)(42)(44)).

The general impression gained from an overall comparison of the heather moorlands of the Wanlockhead and Peebles areas is that within the latter moor burning is perhaps more prevalent and more <u>regularly</u> practised. It is a subject on which farmers and shepherds are certainly more vocal in the Peebles area. As far as could be ascertained, the rotation of burning commonly favoured is, weather permitting, on an average, a seven years one, for these heather moorlands on whose 'hard' land heather growth is reputedly slow[1]. More emphasis, however, was laid and more opinions vouchsafed on the methods of burning - opinions which inevitably reflected differences of approach and of interest as between the sheep farmer and the gamekeeper. While the latter invariably insists on the burning of small strips of heather, and a few acres in extent and widely spaced, in order to maintain sufficient cover for grouse as well as providing fresh feeding - the sheep farmer and shepherd, with the bulkier demands of sheep and the inimical effects of concentrated grazing on small patches in mind, advocates burning over much wider areas. Before 1939, during the era of depressed sheep farming, it has been suggested that much of the heather moorland in the Peebles area was managed in the interests of grouse rather than of sheep and, though not to the same extent as in pre-war days, there are evidences[2] of a

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1
Smith, W.G., (1918b). Also one farmer indicated a heather growth which he maintained to be 20 years old and which was - though woody and inclined to be open - barely 6" long.

2
Author saw two instances of tracks having been recently cut to provide a way for land-rovers up relatively steep and inaccessible hill sides (see F.69 (42)).

renewed interest in grouse shooting and the old controversy between the sheep farmer and the gamekeeper still exists and rankles.

However, throughout the areas indicated as heather moorland on the vegetation map (F. 48) the association does not everywhere maintain a uniformity of composition and pattern. Calluna vulgaris is frequently accompanied by a variety of species, one or other of which may attain local dominance or co-dominance under certain circumstances, as for instance:-

Erica cinerea	(f. a.)	especially on very steep slopes which have been recently burnt and particularly where erosion may have broken the continuity of the peat and vegetation cover - soils often primarily mineral in content on slopes frequently disturbed or screed.
Vaccinium myrtillus	(a→co-d.)	and in some instances dominant, again on very steep slopes disturbed in one way or another.
Galium saxatile Potentilla erecta	(f.)	associates in both pure and mixed heather moor.

Grass, including Aira flexuosa, Nardus stricta, Agrostis spp., Festuca spp., Anthoxanthum odoratum - one or other, or a mixture, of which, often becomes locally dominant, where for one reason or another heather has been temporarily or permanently suppressed.

Hypnum scheberi Polytrichum commune	(o. f.)	where soil conditions are slightly wetter than usual.
Pteridium aquilinum	(a.)	and often (d) below 1250'
Empetrum nigrum Scirpus caespitosus	(o.) (o. f.)	on wetter patches, often of 'puddled' peat.

Only in the somewhat greater abundance of Erica cinerea and Vaccinium myrtillus does the association show any differences in specific composition from that of the Wanlockhead area.

Heather moorland occurs to a lesser or greater degree throughout the Peebles area, over such slopes as provide an adequate measure of free drainage, from 1000', or less in some cases, to a maximum altitude of between 1800'-1900'. The most striking feature of its regional distribution is, as has already been indicated, the concentration and wide development of relatively pure, unbroken, heather dominated moorland in the southern part of the Peebles area. This concentration coincides to no mean extent with a distinct physical region or sub region - the southern Leithen plateau (see F. 44), where dissection of the upland is so markedly deep and close, where very steep slopes (often over 20°+) occupy such a large percentage of the surface area and where the narrow sinuous ridges provide limited, indeed negligible areas of gentle slope on their convexly domed summits (see also F. 41: F. 42). It is 'hard' land 'par excellence' and only scattered remnants of the peat cap of the northern Leithen plateau survive on some of the broader summits, or project tentatively into the area from the north.

However, even in this heather-dominated sub-region the association is far from completely uniform, and much is of a mixed and variable character. But only in a few respects can it be said that its variations exhibit any well marked or particular patterns that can be directly correlated with particular and constant physical factors. One of the most noticeable is to be seen on those particularly steep narrow ridges which, between the Horsburgh and Caddon valleys, trend from north to south. Here the purest and most uniformly unbroken spreads of heather, accompanied by a thin, but continuously and well developed, peaty soil layer, are concentrated over the summits of the ridges and down their slopes to 1500' or even, in some cases 1250' - below which altitudes the heather moorland association becomes more mixed, the number of associated species, particularly grasses, Erica cinerea, Vaccinium myrtillus is higher, bracken increases and may gain local dominance, and the heather-dominated areas are often reduced to widely discontinuous patches; still further downslope it may be replaced by a zone in which bracken and/or grass are dominant and heather may or may not be present (see Diagram 10a opposite p.226 : F.73(65):F.74(66)).

This perceptible thinning and the, what might be called, threadbare appearance of the heather moorland on the "middle slopes" is closely associated with, and related to, an often marked increase of gradient (1:3 or less) over such sites and where over burning has resulted in the exposure and probably the drastic desiccation of the peat layer, and consequently its rapid erosion and, in places, its complete removal. On many of these excessively steep slopes (wherever over 20°) considerable instability results once the equilibrium between the vegetation and the soil, albeit thin, has been upset by mismanagement and, becoming more susceptible to continued erosion under the onslaught of weather, as well as the depredations of sheep, often results in an exposure of the mineral soil, and fine screes[1], devoid of a

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1 Compare with Wanlockhead, where gullying more often results.

vegetation covering, which fan down slope and sterilise wide areas of grazings. On such disturbed slopes the percentage of Vaccinium myrtillus and Erica cinerea is usually high. Fenton who has considered in some detail the problem of slope erosion in relation to vegetation and its management[1] suggests that the probability of erosion following a severe burn of, particularly old, long, heather increases with increasing slope and it occurs most often when slopes approach a gradient of 1:3 or 1:2½, and is further aggravated by the drier climatic conditions of the eastern Southern Uplands. Also, many of the variations in the heather content on slopes of equal steepness may arise from differences of aspect, or local weather conditions prevailing at the time of, or before, burning and which determine the amount of moisture in the soil and the consequent chances of survival of the peat layer.

In some instances, particularly on the higher, upstanding culminations of these ridges, a conspicuous cap of Nardus stricta, where the peaty layer remains but where Calluna has been suppressed or destroyed by the combined effects of over-burning and heavy selective grazing, replaces the usually dominant heather. However, over much of the area the pattern of variations is much more haphazard: with small strips exhibiting every variation from Calluna with mixed grasses and Vaccinium to a complete dominance of Nardus, or wide extents of grass moorland whose abrupt junction

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1 Fenton, E.W., (1951a) pp. 35-42.

with contiguous heather evidences merely the effect of variations in the severity of burning (see F.74 (67)). Vaccinium, whose abundance has already been noted, occasionally becomes completely dominant though it rarely is extensive enough to warrant its recognition as a separate association. Its requirements are similar to those of heather which it may supplant temporarily, after moor burning, or permanently, at high elevations[1 2]. Such may be the case for the compact and fairly wide spread of dominant Vaccinium myrtillus, accompanied by Empetrum nigrum, Juncus squarrosus, Hypnum scheberi, Festuca ovina, Nardus stricta, and occasional Calluna, which occurs over those pimple-like summits of Makeness and Sheildgreen Kipps.

While certain broad and tentative correlations, such as these between landform (expressed largely and primarily in terms of slope conditions) and the variations of the heather moorland, can be drawn on the basis of a regional survey - beyond that it would be unwise and extremely difficult to venture any further generalisations, since the factors involved are so numerous and so complexly inter-related that each vegetation facet may well have developed under a combination or permutation of conditions particular to itself. Fenton, who has studied so intensively the variations within the heather moorlands of South East Scotland, illustrates all too well the multiplicity of variable factors at work and the difficulty of assessing the dominant one in any

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1 Thomas, B., and Dougall, W.H., (1938).

2 Fenton, E.W., (1951a) pp. 44-45.

particular case. Two extracts from his work serve as a fitting conclusion to this necessarily broad discussion of heather dominated moorlands in the Peebles area and as a reminder of the dangers of over-generalisation. He says, "a Heather dominated area may in turn be dominated by Wavy Hair Grass with a mixture of Bent, fine leaved Fescues and Nardus. Each may at times be dominant depending on surface erosion, wastage of peat, conditions of moisture and the biotic factor,"[1].... while he later remarks that, "It is not always easy to fore-tell or even compute the changes of vegetation that may occur on a hill grazing after destruction of surface vegetation by burning or by erosion or by other causes. The factors at work are many and the degree to which they may vary in intensity or operation makes the problem extremely complicated. The difficulty of assessing the factors at work under natural conditions make the problems infinitely more difficult than examining any factor or factors under controlled conditions".[2]

Throughout the northern half of the Peebles area heather moorland rarely covers such extensive areas as it does further south. In some instances entire slopes may be dominated by Calluna from the margin of the peat cap right down to the valley floor, its continuity unbroken even by the usual Nardus zone - though this commonly occurs where, as on left bank of Woolandslee Burn and the slopes of the Trously valley, the margins of the peat

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1 Fenton, E.W., (1951a) p. 37.

2 Fenton, E.W., (1951a) p. 38.

cap are not so noticeably hagged. Also, further north, steep slopes are less widely developed and are frequently confined to altitudes below 1250' (see F.42). Dense patches of heather occur largely in the upper, less accessible and more shaded parts of the valleys and clenchs - but, more frequently, on the steep slopes of the northern part of the area heather occurs mixed with either Nardus, bracken, or a mixed grass association, or as scattered patches within the dry grass moorland, which takes its place in the north of the area.

<u>Dry grass moorland.</u> This association is characteristically dominated by a mixture of several grass species accompanied by, an often wide, variety of other heath plants. It differs from that of the same name in the Wanlockhead area in its larger proportions of Nardus stricta and Aira flexuosa, in the somewhat less striking prevalence of Anthoxanthum odoratum and in the <u>usually</u> complete absence of Molinia caerulea.

Those grasses which occur most frequently and often constitute the bulk of the association include:-

Nardus stricta	(a)	one of other may be locally dominant, usually either Fescue-Agrostis with or without Nardus, or Nardus alone.
Festuca spp. (a) (primarily fine leaved)		
Agrostis spp.	(a)	
Aira flexuosa	(f-a)	
Anthoxanthum odoratum	(f.)	

and are accompanied by:-

Vaccinium myrtillus	(a.)	- often (co-d) with grasses
Potentilla erecta	(f.)	
Galium saxatile	(f-a.)	
Juncus squarrosus	(o.f.)	
Calluna vulgaris	(o.f.)	but never abundant
Empetrum nigrum	(o.)	

Juncus articulatus)
Juncus communis) (l. a.)
Hypnum scheberi (l.)
Polytrichum commune (l. a.)
Pteridium aquilinum (f. d.) below 1250'.

other less frequent associates occasionally met with include -

Viola tricolour
Holcus lanatus
Thymus vulgaris)
Helianthemum Chamaesistus) usually on 'dry flushes'.
Trifolium repens)
Bellis perennis) occasionally at low altitudes near
Thistles) improved land: may have been imported
Plantains) by sheep or represent relicts of a
Deschampsia caespitosus) once improved grassland.
Ulex europeaus - frequently on lower eroded slopes and especially on terraces of either sandy material or boulder clay which have been undercut by river erosion.

The vegetation cover formed by this assemblage of species varies in length, from a relatively long mixture of grasses to a frequently short, well and closely cropped, springy turf composed primarily of fine leaved fescues. Soil conditions associated with it may likewise range from a mineral soil of varying depth and consistency with or without a thin peaty layer which, when present, is often no more than a mat of fibrous plant remains.

As a distinct association, in which neither Nardus nor heather play a conspicuous part, it is relatively restricted in its extent. Although it can and does occur throughout the area on steep well drained slopes from 1000'-1750', it is not only more widespread in the northern part of the area but is most fully developed on steep 'middle slopes' from 1250'/1000' to 1500' across a zone between the fringe of Nardus moor above and the bracken and 'flushed' grass of the lower slopes and valley bottoms.

(see F.72(63):F.72(64):F.78(73)). One of the most continuous areas completely dominated by a practically pure mixed grass association occurs along the north-west facing scarp of the Moorfoots (see F.77(72)). Elsewhere, it may dominate individual hill sides, as for instance Totto Hill, Garvald Law[1] and Dundreich Hill[2]. But, as often, well drained slopes within the northern part of the area carry a more mixed and indeterminate vegetation in which Nardus or heather, or both, frequently occur.

Some of these grass-dominated areas may owe their establishment and composition to richer soil conditions associated with either concentrated sheep dunging, or flushed conditions around springs, or may indeed, in some cases represent once improved and now abandoned fields reverting to a mixed moorland vegetation. The bulk however of the dry grass moorland and areas of mixed grass and heather must be regarded as having been derived from a more continuous heather cover of which the scattered plants, or isolated clumps of Calluna are relicts, in regions that have been subjected to varying degrees of erosion, and/or intense grazing. According to Fenton the suppression of heather can be accounted for by several, usually inter-related factors, including -

1. Over or severe burning which destroys heather shoots and underground parts and allows the establishment of other plants.
2. Heavy grazing of heather areas - and particularly after recent

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1 Map reference /340500.

2 Map reference /269483.

burning.

3. Peat wastage and erosion aggravated, particularly on steep slopes, by a combination of the above factors.

It is worth noting that, on many of the exceptionally steep grass-covered slopes, the dry grass association was commonly in the form of a very closely cropped springy turf composed very largely of fine leaved fescues, with heather when present reduced to isolated, compact, upstanding clumps, the whole often over run with rabbits. Many of such steep grassy slopes were devoid of any peaty layer in the soil, the association was often broken and the underlying mineral soil visible - and from such badly broken patches, often stemming from rabbit burrows, wide, fine, screes fanned down slope. There is little doubt that in places the rabbit is as great, if not a greater menace to grazings than bracken and must be considered, when abundant, as yet another important factor in the destruction of heather[1] and the aggravation of instability and slope erosion.

While, therefore, as in the Wanlockhead area, there is in the Peebles area, as a whole, a broad and well marked degree of correlation between areas of steep slope and those occupied by one type of dry moorland or another - the intermixture of heather and grass serves as a reminder firstly of the interchangeability of what have been considered two district associations; and secondly, that the occurrence of one or another of these associations is largely dependent upon biotic factors whose effect

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[1] Fenton, E. W., (1940)

on the balance of species, and the peat and moisture content of the soil are to no mean extent intimately linked with the degree of steepness of part of a slope and its aspect: but even then, the extent to which physical factors may 'control' or 'modify' the effects of either burning or grazing may be further dependent upon not merely general climatic characteristics but the actual weather conditions prevailing over a relatively short period of time, either directly before or after the operation of the biotic factors. It is not surprising therefore, that to a probably even greater degree than in the case of the wet moorlands, the variagated pattern of the dry moorlands, so dependent upon a complex of factors within which the emphasis is continually changing, show no consistent or particular correlation with one particular physical factor.

Bracken (Pteridium aquilinum). Bracken, as in the Wanlockhead area, is frequent, indeed abundant, throughout the Peebles area over all well drained sites and slopes at lower altitudes, within a zone whose average upper limit, as has been indicated on the vegetation map (see F. 48), is generally in the region of 1250'. However, wide and indeed extreme deviations from this approximate altitudinal limit often occur. Along the Moorfoot edge, and the steep slopes of north Tweedside bracken frequently, probably because of the effects of greater exposure, extends no higher than 1150'-1200'[1]; but, over the steep slopes of most of the

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1 A member of the Forestry Commission gave 1100' as the limit of its growth along the valley slopes north of the Tweed. While most farmers regard 1200' to be the upper limit of luxuriant growth - throughout the area as a whole.

valleys which penetrate the area, it remains vigorous and often dominant up to 1400', while along the deep steep burns and sheltered cleuchs it can maintain itself up to heights of, and occasionally exceeding, 1500'. So that while around the periphery of this small upland area an upper limit of 1200'-1250' is reasonably constant, considerably wide and rapid variations in its altitude occur along tributary valleys - variations which would be difficult and tedious to map exactly and accurately and whose representation on the map would merely lead to considerable confusion and serve no useful purpose.

Within this zone the actual indicence of bracken is very variable, in some instances it is sparse and patchy or even absent while, in others, it may attain absolute dominance. Except in deep cleuchs and alongside some of the smaller burns, it is not often particularly dense or high and is more frequently diffusely spread over a grassy carpet or through an area occupied by mixed grass and heather - frequently in the latter instances where there were evidences of either burning or erosion or both[1]. Local opinion suggests that the area covered by bracken has increased two-fold within the last forty years and unfortunately attempts to check its advance (although most farmers cut some regularly) are made difficult and often unprofitable by frequently steep and inaccessible slope conditions.

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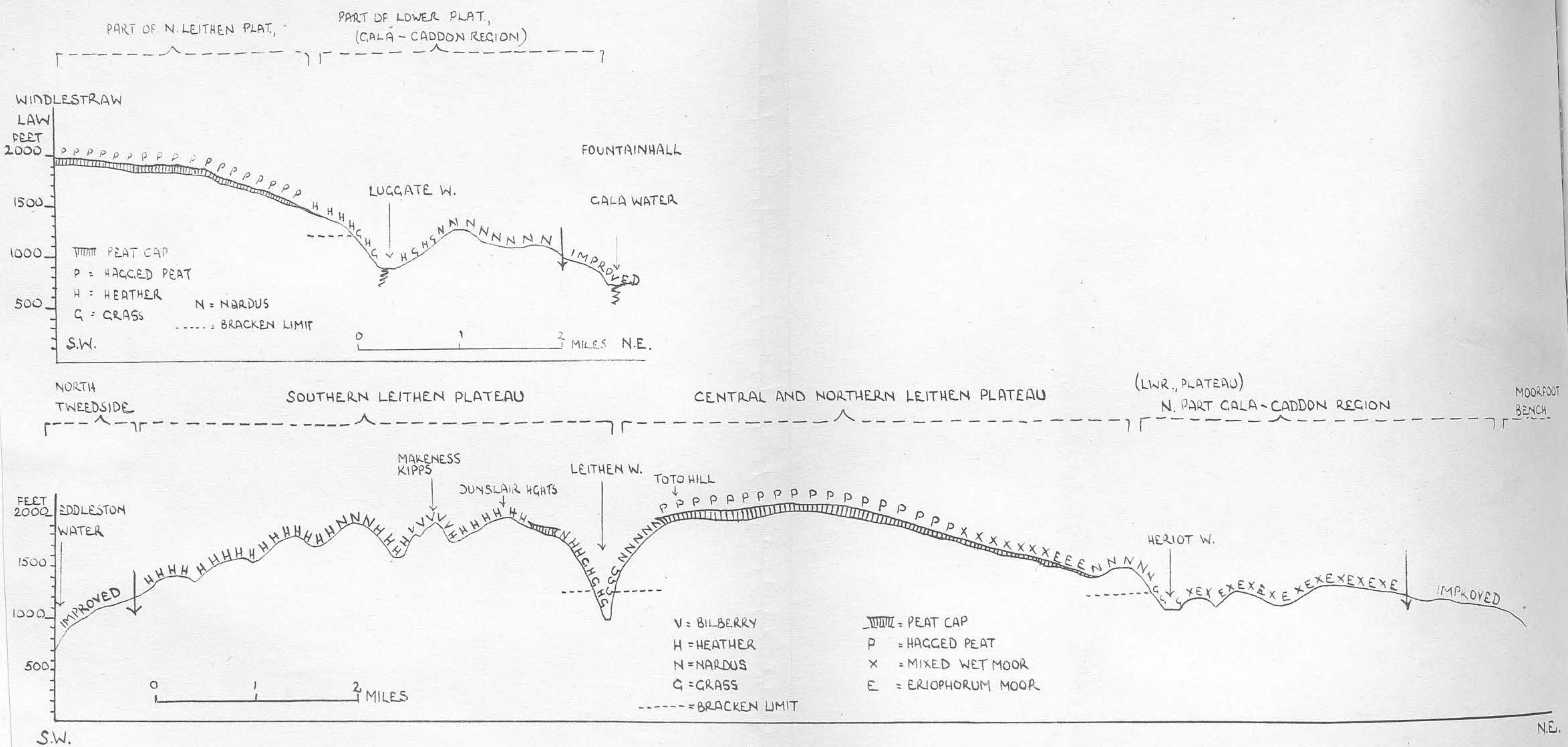
1 Fenton, E.W., (1951a) pp. 46-48; and several local farmers told the author that they had noticed on certain badly burned patches how bracken had come in gradually and established itself.

DIAGRAM 11.



SECTIONS ACROSS PEEBLES AREA SHOWING RELATIONSHIPS OF VEGETATION TO PRINCIPAL PHYSICAL SUB-REGIONS.

The following table and accompanying diagram (see Diagram 11 opposite) attempt to summarise the general characteristics of the physical regions (or sub-regions) in the Peebles area and to indicate the types of vegetation (associations) which occur most prevalently within each.

Attempted correlation of vegetation association with Physical Regions (or sub-regions): definition of sub-regions based on Linton's classification. (See F.44 and F.48)

Physical Regions	Principal landform features	Associated Vegetation
Leithen (L) Plateau	forms 'core' of area. High massive plateau 1500/1750-2000'; general altitude of summit levels 1700'-1800' with 5-6 summits over 2000'; sub-maturely dissected with the difference in dissection between north and south of plateau allowing further sub-division into:-	
Northern (L2) Plateau	less deeply and closely dissected: valleys with floors usually over 1000'/1250' - some 250'-500' deep; lower valley side slopes moderately steep generally convex giving way to broad gently sloping convex ridge crests and summits. Areas of gentle slope between 2000'-1500' fairly extensive.)	Fairly extensive hagged peat caps between 2000'-1750' - fringed with Nardus Moor in the south and west and with mixed wet moor and Nardus at 1750'-1500' in the north and east.
Central (L1.1) Plateau	represents the southern margin of L2 - similar but more deeply dissected: deep, steep, valley side slopes but broad convex ridges still preserved.)	Steep Slopes carrying heather moorland and/or dry grass moorland - rather more grass than heather.
Southern (L1) Plateau	Deeply and closely dissected: valleys 750'-1000' deep: steep slopes often over 1:3 culminating in numerous narrow undulating convex ridge crests aligned N-S: Areas of gentle slope negligible: Valley floors all below 1200' and often broad and wide at lower ends. Valley heads frequently nivated amphitheatres (hopes): often intense headward erosion.	'Hard' land-peat or peaty layer thin, dry, (or absent) heather (or Vaccinium) moorland dominant on ridges grading into heather and grass on steep often screed slopes - rather more heather than grass

Physical Regions	Principal landform features	Associated Vegetation
Upper Gala Region (G) (or Lower Plateau)	Polycyclic upland: Hills rounded and subdued with often broad summits between 1200'-1500'. Slopes above 1000' level always gentle (<10°): Below 1000' valley side slopes are steep especially along Heriot, Luggate and Gala Waters: Tributary streams hardly more than narrow V-shaped notches which dissect surface above 1000' into a number of long, often broad spurs trending W-E or NW-SE. Dissection less towards the north where, especially north of Heriot Water, broad gently sloping poorly drained surfaces occur between 1500'-1200'.	On very steep valley slopes grass or grass/heather/bracken abundant: gorse, frequent: many valley slopes, 10° or less, cultivated. Gently sloping areas 1000'-1250'/1300' improved: agricultural land more prevalent in south: gentle slopes over 1250' mixed wet moor, Eriophorum or Nardus depending on drainage conditions, more prevalent in North.
Moorfoot (M) Branch	(- largely without the area surveyed -) For most part a broad shallow depression 1000'-750' sloping from edge of Moorfoot scarp north westwards: drift covered: faintly corrugated with low swells	Sandy light soils usually cultivated - but poor drainage on heavy till has resulted in much of the area being under rough grazings either Nardus moor or mixed wet moor.
North (T) Tweedside	A region of hill and valley slopes unified by through flowing R. Tweed. A former Tweed Valley floor at approx. 1200'-1300' has been dissected to give a series of long spurs, backed at inner northern and N. eastern ends by rising ground and by truncated spurs at valley ends. Represents the ends of the ridges of the Southern Plateau - with summits broader and giving wider areas of gentle slope above the Eddelston than above Tweed valley.	heather and/or grass on exceptionally steep slopes e.g. north of R. Tweed between Innerleithen and Thornylee. Otherwise all, but areas over 1300', cultivated or improved.
Eddleston Valley (E)	Bench land similar to Moorfoot edge cut in a N-S direction by trough of Eddleston valley: eastern slopes generally steep: plastered with boulder clay up to 800'; bench between 800'-1000' considerably dissected.	- all improved -
Caddon- (C) Gala Region (Caddon Embayment)	Hilly region formed by moderately deep dissection of a surface at 1300'-1400' overlooked by dissected Leithen Plateau to the north west: stream dissection in both a NW-SE and SSE-NNW directions resulted in small lumpy hills rising by steep slopes to 1100'-1400' above gentler drift mantled slopes between 900'-600' and in which valleys are incised some 150'-200'	Below 1200'/1000' largely improved or cultivated 1100' heather moorland or mixed grass and heather

Perhaps the principal, and one might venture to say, only clear, definite, and unqualified statement that can be offered on the relationship between vegetation and physical features is that the regions so defined and delimited provide certain assemblages, combinations of slope conditions, which under certain climatic conditions (may) determine the predominance of either dry or wet moorland or improved land. To a certain, though somewhat limited, extent the specific composition of the vegetation may be dependent upon altitude, in combination with slope conditions. Further than that it is impossible to press the correlation. The associations within either the wet or dry moorlands are more frequently determined by biotic factors (whose intensity frequently varies with altitude and accessibility) working on a complex of different "slope facets" within the broader physical regions or sub-regions.

SECTION V.

COMPARISONS AND CONCLUSIONS.

CHAPTER XII

Climate: Contrasts and Comparisons.

The preceding detailed analyses of the various types of vegetation in their particular relation to physical sites has largely, and of necessity, tended to emphasise and to qualify more clearly and in greater detail those principal contrasts of landform - of surface configuration - originally postulated for the south-west and north-east of the Southern Uplands and presented by the different assemblages of landforms within the three sample areas of Newton Stewart, Wanlockhead and Peebles. The original fact remains, and emerges even more clearly however, in spite of increasingly detailed analysis and description of relief and landform, that the principal contrast in this respect as between the Newton Stewart area and the two more closely allied central and eastern areas is dependent on one basic, fundamental, and indeed simple physical factor - the ridged and mammilated nature of the land-surface in the south-west where, in striking contrast to those areas east of the River Nith, smooth slopes of any degree are at a minimum; and further, it is most probably the only landform feature which alone may be confidently considered as being responsible for differences in the distribution and the character of the vegetation as between the three areas. In other respects differences and contrasts of landform arise mainly from the relative extent in any one area of steep, intermediate, or gentle slopes and also, from the variations in altitude at which the more extensive areas of gentle slope are developed. But rarely can the effect of differing degrees of slope and altitude be divorced from a consideration of the closely related effects of climate - and in particular, annual rainfall and its effectiveness as controlled by a complex of both temperature and relief in any particular area.

The regional climatic contrasts revealed by lowland meteorological stations and reflected broadly in certain respects within the three sample areas are however, as already indicated, very much more difficult to define and qualify precisely for these essentially upland districts. The necessary data is not available, unfortunately. Meteorological records for stations above 500' are scarce, above 1000' rare and further, with but few exceptions, even the lowland meteorological records available for the three areas under consideration are generally, and often actually, without the particular area or are, at most, confined strictly to its periphery. Also, those records available for stations contiguous to each of the areas are of a very variable nature and, to recapitulate, come from a number of sources among which the most important and relevant, as far as this study is concerned are:-

1. Reliable long term averages published by the Meteorological Office of the Air Ministry[1]. These provide in all, however, only three stations which are situated anywhere near the areas in question: Newton Stewart area; Cally - Kirkcudbrightshire (120') monthly means of temperature and rainfall: Wanlockhead

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[1] Meteorological Office (1920); (1933); (1936).

area; Drumlanrig - Lanarkshire (160') monthly means of rainfall: Peebles area; West Linton (820') Midlothian - monthly means of temperature: Edinburgh (Blackford Hill - 441') - Midlothian - monthly means of temperature and rainfall.

2. Unpublished meteorological Office yearly summaries[1] of climatic elements for a small number of stations. These, however, are of very limited use in that the records are not always continuous or complete and, at most, cover only relatively short periods - as for example:-

Leadhills	(1310')	1914-27
Peebles	(525')	(1934-38
		(1942-46
Newton Stewart	(75')	1939-43
Glenlee Power Station	(181')	1937-49

3. Probably, as far as individual stations are concerned, one of the most valuable sources of material for meteorological data in the South of Scotland are those articles published by Alexander Buchan[2] during the last century. These offer reasonably long term averages for certain climatological elements, in particular temperature, rainfall, and wind. Although the averages provided are for an earlier period (generally 1856-1895) than those supplied by the Meteorological Office to-day, they compare very favourably with these later records - variations are not great between closely adjacent or similar stations for which averages are available from both Buchan and the Air Ministry. Also, they are extremely useful in this study, providing as they do the only records of

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1 Obtained from Meteorological Office, Palmerston Place, Edinburgh: the author is indebted to Mr. Thompson of this office for making these records available.

2 Buchan, A., (1870-73) (1894); (1898).

mean monthly temperatures close to, and often well within, the three upland areas.

4. The somewhat sparse rainfall averages can be supplemented from numerous and often long term records published yearly in British Rainfall[1]. Many of these are for stations within or around these particular upland areas, and also at relatively high altitudes.

Nevertheless, in spite of this wide variety of sources, instrumental records of any kind or value are commonly confined to altitudes below 1000', and from these must be deduced, as far as is possible, the climatic conditions for the main mass and extent of each of the three areas which lies well above this altitude. Discrepancies arising from the varying altitudes at which these available stations are situated can often be, as in the case of temperature conditions, eliminated by reducing or increasing monthly and annual means to a common altitude or altitudes. This has, in fact, been done in many instances. However a more serious disadvantage in attempting to compare the individual records for groups of adjacent stations, even after allowances have been made for varying heights, is that in many cases the averages were computed from observations ranging over very divergent lengths and periods of time. However, it was considered that the limited and scattered nature of these available records did not really justify the expenditure of time that would have been necessary to weigh short term against the more reliable

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1 Meteorological Office (1903-).

long term averages. In any case the Climatological Atlas of the British Isles[1] does provide an alternative, and indeed invaluable, summary of the distribution of monthly and annual averages of all climatological elements within Britain, and from its numerous isopleth maps a useful picture of the average conditions can be formed for the districts in which each of the three areas surveyed are situated. However, in view of the small scales of most of the maps provided in this atlas, and the fact that many elements have been reduced to sea-level values, the quantitative measurements available for the areas in question must of necessity be of a very generalised nature. Yet, in so far as these records provide, in contrast to the data available for individual stations, a standardised basis for the comparison of the climatic conditions as between the three relevant regions of the Southern Uplands recourse must be, and has been, made primarily and constantly to this publication for quantitative data.

On the basis of records from individual lowland stations and "district" averages certain contrasts in climatic conditions as between the three areas of Newton Stewart, Wanlockhead and Peebles, are revealed - particularly of rainfall and temperature, those two elements which play such a dominant role in the determination of the character and distribution of vegetation. How far however can these contrasts in regional climates be qualified for these particular upland areas, and how far are they maintained, as they seem to be in certain respects, in spite of increased rainfall,

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1 Meteorological Office (1952).

lowered temperatures, and increased exposure imposed by the often large ranges of altitude within each area? In an effort to answer, or suggest an answer to, this question, to state more precisely and quantitatively the 'local' climatic conditions, and to provide a basis for a comparison of the three areas under the influence of increasing altitude, an attempt has been made to deduce, largely by means of interpolation from available lowland data, the progressive modification of climatic conditions at high, selected altitudes.

The altitudes for which it was decided to assess climatic conditions were chosen with a view to providing an evenly graduated cross-section of the general range of altitude from 500' up to 2000' and to facilitating comparisons, remain the same in all three areas. While these selected levels, separated by a 500' interval, are and must be arbitarily chosen, they do nevertheless reveal a general coincidence with certain significant, and primarily, landform features - taken as they have been at the following altitudes of:-

a) 500' - an altitude representative of the general average height of the periphery of each area, i.e. the principal valley floors surrounding the hill land and usually, but not always, areas of arable cultivation.

b) 1000' - in all three areas the 1000' contour line coincides approximately with the inner margin of what may be termed the 'low' as distinct from the 'high' moors. The former are most widely developed within the

Newton Stewart area, to a lesser extent around Wanlockhead and largely without or on the margins of the Peebles area. But in each case they are at this altitude, separated, often very abruptly, from the high moors by a sharp topographical break evidenced by increasing gradients. Also, though in a more approximate and generalised manner, this altitude of a 1000' may be considered as representative of the average maximum upper limit of <u>arable</u> cultivation and of luxuriant bracken growth.

c) 1500' -
d) 2000' - these two higher altitudes coincide with the approximate and average upper limits of two usually well-marked plateau levels which occur throughout all three areas, to a lesser or greater degree.

<u>Rainfall</u>: More abundant and reliable long term data are available about rainfall amount and incidence for upland areas than for any other measurable meteorological element. This arises from the fact that not only are the voluntary rainfall records published yearly in British Rainfall numerous and widespread for both lowland and upland areas, but also that most of the reliable rainfall maps produced by the Meteorological Office and showing annual and monthly mean isohyets, of whatever scale, illustrate the influence of relief and, in particular, increasing altitude on rainfall amounts and distribution. Both the rainfall maps in the Climatological Atlas of the British Isles and those provisional $\frac{1}{4}$" isohyetal maps of average annual rainfall compiled by the

Meteorological Office (see Maps F.10 F.31 and F.46) suggest that the decrease in the average annual rainfall as between the south-west and the north-east of the Southern Uplands is maintained, despite the actual increase of rainfall amount with altitude, from 500' - 2000' in each of the three areas. This is illustrated further by the approximate rainfall figures for the selected altitudes in each individual area, given below:-

<u>Average Annual Rainfall</u>

AREA	N. STEWART	W'LOCKHEAD	PEEBLES
SOURCE	Prov. $\frac{1}{4}$" maps	Prov. $\frac{1}{4}$" maps	Prov. $\frac{1}{4}$" maps
Approximately at 500'	45"-50"	45"-50"	35"
at 1000'	60"-65"	60"	40"
at 1500'	70"	60"-70"	45"
at 2000'	70"+	70"+	45"-50"+

The seasonal incidence, however, is strictly comparable throughout except in that the secondary summer rainfall maximum, occurring in either July and/or August, and common to all three areas, is more pronounced in the two drier eastern, and in particular the Peebles, areas, though it is not necessarily, nor is it in fact, higher in actual amount than in the south-west. Also, while all these areas have a similar average number of rain days of 225 per annum, the somewhat lower rainfall of the Peebles area, particularly in winter and early spring, is reflected in certain slightly lower monthly averages when the number of rain days is 17/20 Nov.,

20. Dec., 20. Jan., in contrast to an average of 20, 23, 23, respectively for the same months in the other two areas; while the 'dry' months of March (17/20 rain days) and September (17/14 rain days) also give slightly lower values in the Peebles area than in the corresponding months in the Newton Stewart and Wanlockhead areas, the latter with averages of 20 and 17 rain days respectively. The occurrence and prevalence of dry and droughty, as against wet and rainy spells, within each of the three areas, suggested by the district values provided by the Climatological Atlas of the British Isles and given below, further serves to reflect and complement these contrasts of rainfall as between the south-west and the north-east of the Southern Uplands.

Greatest number of consecutive days without measureable rain (1887-1947).

N.S. 30	W.L.H. 30-	P. 30+

Greatest number of consecutive days with measurable rain (1903-1947).

N.S. 50	W.L.H. 50	P. 30-40.

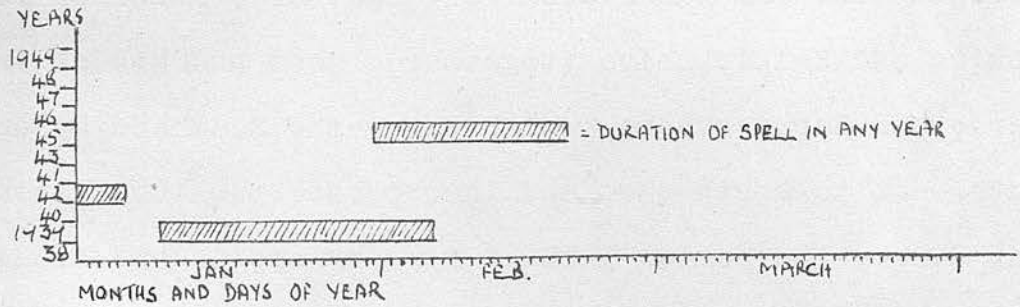
The seasonal incidence and prevalence of dry and wet spells can exercise an influence of considerable importance on the vegetation of a particular area - especially, as Fenton points out, in affecting the establishment of vegetation in upland areas after moor-burning and the liability, dependent upon the success or failure of this practise, of soil and peat wastage and erosion[1]. This aspect prompted, and appeared to justify, a closer and more

[1] Fenton, E.W., (1951a) pp. 38-52.

detailed investigation of the seasonal incidence, and frequency of dry and wet spells in the south of Scotland with a view to assessing whether, over long periods, any significant variations as between the three areas surveyed were liable to occur. Material for such an analysis is provided by the records of dry spells, absolute, and partial drought, rainy and wet spells published annually in British Rainfall from at least 1903 onwards. Within the various counties from which such spells are recorded the same station, or stations, are however not always used consistently throughout a period of, at least, thirty years. However, it was considered justifiable and reasonable, for the purpose of what, at best, could be no more than a broad and very general assessment, to assume that (particularly for dry spells or droughts) the meteorological conditions associated with a long period (15-29 days) with little or no rain would probably be fairly widespread; provided, therefore, that a consecutive run of years was available the actual recording station used within any particular county could vary from time to time without necessarily invalidating seriously such an analysis. The same assumption has been made for the incidence and distribution of wet and rainy spells within any one county although, in this instance, in view of the often localised distribution of rainfall and the effects of topography on its distribution, the widespread prevalence of atmospheric conditions associated with prolonged rainfall cannot be expected with the same degree of confidence as

DIAGRAM 12.

METHOD OF ORIGINAL ANALYSIS OF WET AN DRY SPELLS etc.,



EG., NO. OF TIMES 1st JAN OCCURRED WITHIN A GIVEN SPELL = 1

" " " 1st FEB " " " " " = 2 AND SO ON.

in the case of absolute drought. However, in the absence of consistent records over long periods (at least 30 years) for any one particular station, the same procedure has been adopted in the analysis of both dry and wet spells. Also, while emphasis is placed on the former periods as of generally greater importance in their total effects on vegetation, the latter provide yet another basis for the comparison of the three areas and are naturally complementary to the former.

Hence, for the counties of Ayrshire; Wigtownshire; Kirkcudbrightshire and Dumfriesshire (together); Lanarkshire; Peeblesshire and Selkirkshire (together); West and Midlothian (together); and Berwickshire, which cover the Southern Uplands from south-west to north-east and incorporate the three areas in question, during the period 1919-46 for dry spells and droughts[1], and 1914-1946 for rainy and wet spells[2], the length of such periods so defined in each consecutive year was plotted according to the dates of its commencement and termination (see Diagram 12 opposite); the particular station used was taken as representative of the whole of a county, or named area. From the diagram so constructed the total number of times any particular day of the year occurred within one of the defined periods was then plotted in graph form -

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1

dry spell	= Period of at least 15 days none of which is credited with .04" rain or more.
partial drought	= Period of at least 29 consecutive days the mean annual rainfall of which does not exceed .01".
absolute drought	= Period of at least 15 days none of which is credited with .01" rain or more.

2

rainy spell	= Period of at least 15 consecutive days each credited with .01" rain or more.
wet spell	= Period of at least 15 consecutive days each credited with .04" or more.

see (F. 49) and (F. 50) respectively. By such a means a general diagrammatic representation of the comparative and relative frequency of occurrence of dry or wet periods at different times of the year can be rapidly assessed. The value of such an analysis and the method of investigation employed here lies primarily, and only, in the basis it provides for the comparison of a wide area such as Southern Scotland or of the relative seasonal incidence of such periods throughout the year in any one county.

Considering first the incidence and prevalence of dry spells, partial, and absolute drought as indicated on (F. 49), several note-worthy features are revealed. The well marked seasonal incidence of dry spells from March to June, and again between September and October, coinciding with those periods when the mean monthly rainfall is at a minimum, serves to reflect and re-emphasise the seasonal incidence of rainfall. The graphs also suggest a tendency for the incidence of dry spells and droughts to be most strongly marked and concentrated in spring and early summer, and particularly, from mid-February to mid-March, from mid-April to mid-May and again from the end of May until the end of June - during which periods absolute drought <u>may</u> occur on an average of once in every 6 - 15 years. The secondary 'dry period' of the year, from September to October, is not so conspicuous with a suggested average drought incidence of only once in every ten to thirteen years.

As far as moorland vegetation is concerned, the critical period must also be very closely related to that period of time during which moor-burning can be, and is, legally conducted i.e. from 10th December to the 10th, or under certain circumstances, the 25th April. Dry spells and prolonged drought during this period and particularly prior to any given burn will tend, dependent of course on the age of heather, and the depth and moisture content of the peat or peaty soil, to aggravate the severity of a burn, and hence to lessen the chances of vegetation (and in particular of heather) recovery; also, protracted dry conditions immediately succeeding this period may, as already suggested, seriously check the establishment of a vegetation cover by increasing the liability to severe erosion, on either steep or gentle slopes, under the combined effects of wind, rain, and overgrazing, among other factors, coming into play at a later date. It is worthy of note, therefore, that the graphs suggest that absolute drought may be expected in every county directly after the moor-burning period from the end of April to mid-May at <u>least</u> once in a thirty year period; dry spells occur more frequently. This is not particularly serious and indeed could probably be considered as of negligible importance in the western counties with their higher annual and particularly winter rainfalls, and generally higher atmospheric humidity. It is more significant that in the eastern counties of Peeblesshire - Selkirkshire, West and Midlothian, and Berwickshire, with their considerably lower rainfalls, the incidence of absolute drought immediately after the moor-burning period appears, according to this analysis -

somewhat higher, of the order of once every five to seven years. However, it is only in this respect that the analysis reveals any obvious contrast between the east and west of Southern Scotland, and the fact that it is not a particularly striking contrast is not altogether surprising if it is assumed, as has been done, that drought conditions may often be widespread and be experienced simultaneously over very wide areas. Rather, in a search for contrasts as between the west and east of Southern Scotland, the diagram suggests the somewhat anomalous fact, in view of rainfall amounts, that the prevalence of dry spells particularly from February to March is greater in Kirkcudbrightshire and Lanarkshire than elsewhere; while also in June, and again in September and October the three western counties tend to have the highest incidence of dry spells. On the other hand, the analysis of wet and rainy spells - and particularly the latter - reveal and reflect (see F. 50) much more strikingly and consistently, not only the general and usual seasonal incidence of rainfall with a winter maximum from October to February and secondary maximum in July and/or August, <u>but</u> also the fact that the incidence of such spells at these times is higher in the western counties of Wigtownshire, Ayrshire, Kirkcudbrightshire and Lanarkshire than further east.

<u>Temperature</u>: If only as the ultimate and most important direct source of moisture for plants must rainfall be considered as one of, if not the, most vital of the climatic elements. However, its effectiveness in any area, in determining soil characteristics

and the related type of vegetation, is very closely controlled by concurrent temperature conditions. The humidity of the atmosphere, and the consequent loss of water from both soil and plant, are dependent upon, while the rate of intensity and duration of active growth is, to no mean extent, determined by, air temperatures. As Tansley expresses it, "the luxuriance of the 'average' plant (mesophyte) increases with the increase of both (within limits of course) heat and moisture in a balanced ratio"[1]. Temperature recordings are however much less prolific than those for rainfall, and efforts to estimate from available data possible temperature conditions at selected high altitudes are fraught with difficulties. A tentative attempt nevertheless has been made, using Meteorological Office (principally for the period 1881-1915) and Buchan's (for the period 1856-1895) averages, together with a few other records of variable length, to deduce mean monthly temperature conditions at the selected altitudes of 500', 1000', 1500' and 2000', by allowing for, according to the usual practice, a reduction of 1° for every 300' increase in height.[2] At best, such results as are obtained by this method must be very broad generalisations whose only useful purpose, as is so often the case, is as a basis for comparison between two individual stations or two or more widely separated areas. However, the difficulty of assessing from any group of records what conditions might be at nearby, but higher, altitudes is aggravated in this

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1 Tansley, A.G., (1949a) p. 30.

2 Bilham, E.G., (1938) p. 142.

respect by two other factors: first, the different periods of time from which the available averages have been computed; second, the influence of topography especially around the periphery of the upland areas in question. In the latter case, relevant stations are often situated in deep, sheltered, and enclosed valleys - topographical positions which may tend either to result in very low mean minimum temperatures, particularly where there is a liability for cold air to collect and stagnate, or, where aspect is particularly favourable, to produce exceptionally high mean maxima. For three or four stations around any area the results obtained by estimating temperature conditions for selected altitudes may be so widely divergent as to be almost incomparable and from such it is difficult, indeed impossible, to deduce any reasonably general or useful climate characteristics or contrasts. And although one must wholeheartedly agree with Tansley when he states that, "monthly means for actual stations give a better picture of climate in relation to vegetation than average temperatures representative of districts"[1] - in view of the scarcity of reliable long term averages, and the difficulties arising from the factors just outlined, it is considered that, in this particular respect, district values are in fact <u>more</u> valuable and reliable in providing a sounder, and, above all standardised, basis from which temperature reductions for altitude can be claculated and from which subsequent comparisons can be drawn.

The following table illustrates for selected averages the

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[1] Tansley, A.G., (1949a) p.55.

variations with altitude that might be expected to occur within the three areas. To facilitate a comparison the figures deduced from district averages are separated from those estimated from a group of individual stations.

ESTIMATED MEAN TEMPERATURES AT SELECTED ALTITUDES

	NEWTON STEWART		WANLOCKHEAD		PEEBLES	
°Fahr.	Dist.	Individual Stations	Dist.	Individual Stations	Dist.	Individual Stations
Mean Annual 1000'	44.0	44.6→43.8	43.7	43.1→43.9	43.0	43.4→44.0
1500'	43.0	43.1→41.3	42.0	42.1→42.5	42.0	42.4→42.1
2000'	41.0	41.1→40.4	40.0	40.4→40.9	40.0	40.7→40.6
Mean of Coldest Month 1000'	36.7	35.3→32.1	35.0	34.8→33.4	35.0	34.5→34.2
1500'	35.0	33.8→30.3	34.0	33.4→33.2	34.0	33.2→32.6
2000'	33.4	32.0→28.6	32.0	32.7→31.8	32.0	31.5→31.0
Mean of Warmest Month 1000'	54.0	52.2→54.1	54.0	54.5→53.9	54.0	55.7→54.5
1500'	53.0	53.7→52.1	53.0	53.1→52.3	53.0	54.0→53.5
2000'	51.0	51.8→50.9	51.0	50.2→50.6	51.0	
Mean Minimum of Coldest Month 1000'	—	—	—	—	—	—
1500'	—	—	—	—	—	—
2000'	29.0/28.0	23.0→27.0	27.4	27.8	26.4	—
Mean Maximum of Warmest Month 1000'	—	—	—	—	—	—
1500'	—	—	—	—	—	—
2000'	59.4	57.4→59.5	59.4	52.1	59.9	—

It will be appreciated that, although the estimated values derived from the groups of stations approximate at times very closely to, and on the whole reveal largely similar differences as between the three districts as do those deducted from "district" values, the range of values indicated by the former does not allow the same ease of comparison as the latter averages. It should be noted also that the estimated mean values for "districts" are always inclined to be slightly higher (a difference that is more noticeably marked in the colder than in the warmer months) than those for individual, or groups of individual, stations; and although this difference is only of the order of 1°, it is a fact that must be kept in mind whenever "district" values are being used and compared.

The facts revealed by the table (estimated mean temperatures at selected altitudes) are not in themselves particularly startling or unexpected - and a decrease of temperatures of 1° per 300', resulting in a reduction by approximately 6° of the mean monthly values as between sea-level and 2000' suggests in all areas mean temperatures for the coldest month at the highest altitudes which fluctuate either a little above or a little below 32°, with correspondingly low summer temperatures, of the order of 50°F. for the mean of the warmest month. If the values estimated from either "districts" or groups of stations in each of the three areas are compared it will also be seen that the differences revealed are not great as between the Newton Stewart, Wanlockhead and Peebles areas - again, only of the order of approximately 1°F. and such differences as exist between the three areas are maintained, as would be expected in view of the methods employed, in the same proportions at all altitudes. However, while the milder temperature conditions of the Newton Stewart area as against those of the other two have been assumed initially and the table merely corroborates this fact, a consideration of the estimated figures serves to emphasise the essential <u>nature</u> of these temperature conditions and differences. The principal difference hinges mainly on the slightly higher (though only about 1°) mean annual, and mean and mean minimum values of the <u>coldest</u> month in the Newton Stewart area as compared with those for the same month in the more closely similar Wanlockhead and Peebles areas. The mean, and mean maximum temperatures for the warmest month show no difference as between the three areas as far as "district" values are concerned. However, although the range of variation given by values estimated from groups of individual stations somewhat obscures the contrasts indicated by "district" figures, there is, nevertheless, an interesting suggestion indicated by the former that the mean temperatures of the warmest month are somewhat higher in the east than in the west. This <u>may</u>, however, as has been suggested, be a result of the favourably exposed topographical sites of such stations as for instance Peebles and Galashiels. However, it serves as a reminder that if this <u>is</u> the case for the whole of the Peebles area it will tend to increase the difference in atmospheric humidity particularly in the summer months as between the east and west of the Southern Uplands.

Finally, although the method of estimating these averages ensures that the original differences inherent at low altitudes will inevitably be maintained at higher levels it <u>cannot</u> be assumed that this is in fact the case and that the same differences, or degrees of differences, as exist between the three areas at low altitudes will exist at say 2000'. As Manley pertinently observes, "we cannot however be certain that the curve of the annual march of mean temperature assumes exactly the same shape at all levels above sea: in Britain it certainly does not[1]", and further, the lapse rate between valley bottom and hill summit is probably much greater in spring than in autumn. His instrumental recordings at high altitudes in the Pennines indicate the characteristic lag in the spring rise and autumn fall of temperature associated with upland positions[2]. Also, he has noted that although mean temperatures at 1840' in the Pennines differ by only about 5.5°F (no more than would be expected) from a group of lowland stations - mean maxima are somewhat lower (7°) and mean minima higher (3°)[3]. Finally, the very pronounced westerly exposure of the south-west of the Southern Uplands, and the high frequency of low cloud - both of which factors tend to reduce summer, and may also affect winter, temperatures - may well bring the temperature conditions at high altitudes of the south-west into line with those of the north-east. But how slender in fact is the available basis for comparison.

It is, however, to conditions <u>during</u> the summer months, when temperatures are most favourable for plant growth, that, in most

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1 Manley, G., (1945) p. 410.

2 Manley, G., (1943)

3 Manley, G., (1936)

instances, the more direct influence of temperature on vegetation must be sought. In this respect, a similar attempt to assess the effective length of the active growing season at different altitudes, as between the three areas in question, might reasonably be expected to present a clearer and more useful indication of differing temperature conditions and their possible effect on vegetation. It is generally accepted that the average active growing season representative of a cool temperate climate, such as is experienced by the British Isles, is that period in the year when mean monthly temperatures exceed 42°F.[1 2]. The possible variation in the length of this period with height can be assessed from the calculated reduced mean monthly temperatures for selected altitudes - though the method must inevitably be employed subject to all those qualifications which have been outlined for the estimation of reduced temperatures.

The length of the growing period at various altitudes has been indicated on the individual temperature graphs drawn for each of the three areas (see F. 11, F. 32, and F. 47) by indicating where the annual temperature curve intersects the 42°F level at any of the selected altitudes. However, in these instances, the definition of the length of the growing season in terms of months and part-months is inclined to obscure the more gradual decrease with increasing altitude. In order, therefore, to obtain a more precise quantitative basis for a comparison of the three areas at

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1 Manley, G., (1945) p. 409-410.

2 Pearsall, W.H., (1950) p. 34.

NEWTON STEWART AREA

ESTIMATED APPROXIMATE LENGTH OF 'ACTIVE GROWING' PERIOD AT SELECTED ALTITUDES.

STATIONS		At Altitude of station	Days	At 500'	Days	At 1000'	Days	At 1500'	Days	At 2000'	Days
NEWTON STEWART DISTRICT Sea Level 1901-1930 from Climatological Atlas of Brit. Isles	Max		365		365	21Fe-12Dec	294	5Mar-24Nov	264	25Mar-13No	234
	Mean	24Mar-30Nov	251	5Ap-14Nov	223	17Ap-1Nov	198	25Ap-20Oct	178	4May-11Oc	161
	Min	9May-24Oct	168	26May-14Oc	141	3Jun-29Sep	118	15Jun-15Se	92	28Jun-3Se	71
CALLY 120' 1881-1915 BOOK OF NORMALS	Max		365	14Jan-4Jan	355	24Fe-4Dec	283	11Mar-21No	255	23Mar-12No	234
	Mean	26Mar-16Nov	235	5Ap-8Nov	217	17Ap-27Oct	193	26Ap-19Oct	176	6May-10Oc	157
	Min	19May-6Oct	140	26May-28Se	125	6Jun-17Sep	103	4Jun-4Sep	92	29Jun-19Au	51
KIRKCOWAN 140' 1856-1895 Buchan	Max Mean Min	26Mar-12Nov	231	2Ap-6Nov	218	11Ap-28Oct	198	21Ap-19Oct	181	4May-12Oc	161
* GLENLEE 181' 1856-1895 Buchan	Max		365	28Jan-4Jan	343	19Fe-14Dec	300	1Mar-2Dec	276	11Mar-20N	254
	Mean *	26Mar-8Nov	227	2Ap-3Nov	215	14Ap-25Oct	194	24Ap-17Oct	176	5May-9Oct	156
	Min	22May-1Oct	133	27May-6Oct	131	5Jun-27Sep	114	16Jun-18Se	94	19Jun-1Se	74
NEWTON STEWART 75' 1939-1943 E'BURGH MET. OFFICE	Max	31Jan-29Dec	333	14Feb-15De	304	26Fe-6Dec	283	9Mar-20Nov	256	23Mar-17N	239
	Mean	23Mar-24Nov	246	1Ap-9Nov	223	11Ap-31Oc	203	22Ap-21Oct	182	3May-12Oc	162
	Min	17May-12Oct	148	25May-4Oct	132	2Jun-27S	117	12Jun-17Se	94	25Jun-5Se	72

* Buchan's figs. 1856-1895; Max. & Min. 1937-1949 from unpublished Met. office records.

WANLOCKHEAD AREA

ESTIMATED APPROXIMATE LENGTH OF 'ACTIVE GROWING' PERIOD AT SELECTED ALTITUDES.

STATIONS		At Altitude of station	Days	At 500'	Days	At 1000'	Days	At 1500'	Days	At 2000'	Days
WANLOCKHEAD District Sea Level 1901-1930 from Climatological Atlas of Brit. Isles	Max		365		365	25Feb-2Dec	283	13Mar-15No	247	24Mar-8No	229
	Mean	22Mar-15Nov	238	2Ap-6Nov	218	16Ap-27Oct	194	26Apr-18Oc	175	5May-10Oc	158
	Min	15May-20Oct	158	27May-8Oct	134	8Jun-23Sep	117	21Jun-12Se	83	5Jul-28Au	54
DRUMLANRIG 120' 1856-1895 Buchan (1898)		22Mar-6Nov	229	4Ap-1Nov	211	12Ap-23Oct	194	22Ap-16Oct	177	4May-9Oct	158
DOUGLAS CAS. 783' 1856-1895 Buchan (1898)		8Ap-30Oct	205			13Ap-25Oct	195	24Ap-16Oct	175	4May-9Oct	158
WANLOCKHEAD 1334' 1856-1895 Buchan (1898)		26Ap-21Oct	178					29Ap-19Oct	173	8May-11Oc	156
LEADHILLS 1310' 1914-1927 E'BURGH MET. OFFICE		12Mar-19Nov	252					17Mar-15No	243	27Mar-9No	227
		24Ap-21Oct	180					26Ap-19Oct	176	6May-11Oc	158
		13Jun-18Sep	127					17Jun-14Se	89	28Jun-1Se	64

PEEBLES AREA

ESTIMATED APPROXIMATE LENGTH OF 'ACTIVE GROWING' PERIOD AT SELECTED ALTITUDES.

STATIONS		At Altitude of station	Days	At 500'	Days	At 1000'	Days	At 1500'	Days	At 2000'	Days
PEEBLES DISTRICT Sea Level 1901-1930 from Climatological Atlas of Brit. Isles	Max		365			18Feb-2De	295	9Mar-14No	250	23Mar-6No	225
	Mean	23Mar-16Nov	238	4Ap-7Nov	217	16Ap-30Oc	197	26Ap-21Oct	178	6May-13O	160
	Min	16May-9Oct	146	28May-29Se	123	9Jun-15Se	98	22Jun-7Sep	77	4Jul-27Au	54
STOBO CASTLE 600' 1856-1895 Buchan (1898)	Mean	7Ap-1Nov	208			15Ap-26Oc	194	25Ap-17Oct	175	4May-9Oct	158
GALASHEILS 416' 1856-1895 Buchan (1898)	Mean	4Ap-2Nov	214	5Ap-1Nov	210	18Ap-21Oc	186	27Ap-13Oct	166	7May-7Oct	153
N. Esk RESERVOIR 1150' 1856-1895 Buchan (1898)	Mean	23Ap-25Oct	185					29Ap-20Oct	174	9May-12Oc	161
PEEBLES (The Glen) 765' 1856-1895 Buchan (1898)	Mean	13Ap-30Oct	200			17Ap-26Oc	192	26Ap-18Oct	175	5May-11Oc	159

given altitudes, it was decided to adopt Manley's suggestion and calculate the actual length of the growing period in numbers of days[1]: the dates for the beginning and end of the period being obtained from the position on a graph (of greatly enlarged scale) where the annual temperature curve of monthly temperatures crosses the 42°F. level - for each of the selected altitudes. The procedure was for every available station, and for "district" values, as indicated on the sample graphs (see F. 51,52,53). The interpolation of dates in this way appears to corroborate to a great extent Manley's contention that while the results so obtained may err by a day or so in either direction, the differences with increase of altitude are so great that errors arising from the obvious imperfections of method can be considered of relative insignificance. Once again, however, the figures obtained cannot be regarded as having any really absolute significance or value, but serve mainly to provide a quantitative basis for comparison.

The results of this method of calculating the length of the active growing season for selected altitudes within each sample area are summarised on the accompanying tables (see opposite). Probably one of the most striking facts which emerges from these tables is the remarkably close degree of correspondence between the dates for the beginning and end respectively of the growing season as given by a group of stations in any one area for any particular altitude. The maximum variations are in the order of

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1 Manley, G., (1945) p. 410.

a week, but are commonly less, and usually of only 2 to 3 days; it is a degree of correspondence that must indeed be surprising in view of what has of necessity been a generalised and somewhat crude method of interpolation, as well as of the variations in the length of the periods from which the original averages were calculated. The range of variation in the length of the growing period given in numbers of days for any altitude in any of the three areas is, however, rather larger.

If, however, every available station within each of the three areas is employed to assess the general, or average, lengths of the growing season at any given altitude, the variations are perhaps of too great an order to allow any clear or significant pattern of contrasts between the Newton Stewart, Wanlockhead and Peebles areas to emerge, as the diagram (see F. 54) illustrates only too well. It certainly indicates the gradual and expected dimunition in length of the period with altitude, that at 2000' representing about 70-75% of the length of the growing season at sea-level; this is equivalent to a decrease of approximately 20 days for every 500' and agrees with Manley's figure of 10 days for every 260' in the North of England[1]. The differences in length of the growing season at any of the selected altitudes on the diagram (F. 54) suggests, if the <u>lowest</u> values only are compared, a gradual and progressive dimunition in time from Newton Stewart by way of Wanlockhead to the Peebles area although the actual <u>amount of difference</u> is relatively small, of the order

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[1] Manley, G., (1951) pp. 43-69.

of 2-5 days; also, it would appear that the original difference at sea-level of 14 days as between the Newton Stewart and the other two areas together is much less at 2000' - a fact that might be expected in view of the lower temperatures, particularly in the spring months, at higher altitudes. On the other hand a comparison of the <u>highest</u> values indicated on the diagram (F. 54) suggests that for altitudes of 1000'+ the total length of the growing period in the Peebles area is somewhat longer than in the Wanlockhead area. However, a comparison of values deduced from 'district' averages alone - if only in so far as such figures apply to a standardised position and period of time - give a clearer and more simplified indication of the inherent differences in the length of the growing season between the three areas. These values have been extracted and summarised diagrammatically (see F. 55c). Again, the principal features are reflected: the gradual diminution in the length of the growing season with altitude; the same relatively slight differences as between the three areas which are maintained up to 2000', though (as far as mean monthly temperatures over 42°F are concerned) they are less marked at the highest than at the lowest altitudes; the length of the growing period is greatest at all altitudes for the Newton Stewart area; and also, while the growing period is closely comparable within the Wanlockhead and Peebles areas, it is at every altitude <u>slightly</u> longer for the latter area.

These differences are also to a certain extent reflected in the length of that period during which mean <u>maximum</u> monthly temperatures exceed 42°F - but only over 1000'. On the other hand, the period during which mean minimum monthly temperatures are less than 42°F is at all altitudes shorter in the Peebles than in the Wanlockhead area - reflecting no doubt the fact that mean minimum temperatures, especially in spring and early summer months may, due to the influence of dominant east winds and haar, be lower in the former area. By and large however, although the differences in the length of the growing season, as between the three areas, and evidenced at low altitudes, are maintained at greater heights there is a suggestion that they do become ameloriated and less striking with increasing altitude: but nowhere are they outstanding.

Similar temperature relationships between the three areas are further reflected in the incidence and length of the frost free period, as indicated by the Climatological Atlas of the British Isles, and in the ratio between this period and the length of the active growing season as is indicated in the following table:-

	Newton Stewart area.	Wanlockhead area.	Peebles area.
Average dates of first and last screen frosts.	1 May/15 May → 1 Oct./15 Oct.	15 May/1 June → 15 Sept./1 Oct.	15 May → 15 Sept./1 Oct.
Average number of frost free days.	168 → 138	138 → 107	138 → 122
Ratio of frost free period to active growing period.	67% → 57%	57% → 45%	57% → 50%

The principal difference again lies between the Newton Stewart and the two more closely comparable Wanlockhead and Peebles areas together; but of the two latter areas, Peebles still possesses a slight advantage over the former.

However, as has been pointed out time and time again by ecological and climatological workers, the main disadvantage of using such a simple and generalised method of comparing growing conditions at different altitudes lies in the fact that it does not, and cannot, take into account the fact that, within the period so defined as the 'active growing season', the <u>intensity</u> as distinct from the duration of growth is very closely allied to the <u>actual</u> mean temperatures and particularly to the amount by which these exceed that at which growth is initiated and which, have above all, a strong cumulative effect on plant growth. Some method, therefore, which will allow a comparison of this cumulative effect of mean temperatures over 42°F at different altitudes must be expected to give yet a greater appreciation of the quality and effectiveness of the growing season; also, since it will take into account <u>actual</u> mean temperatures it should be a more accurate assessment of the degree of difference in expected growth at different altitudes.

The calculation of such 'accumulated temperatures' (or the 'Remainder Index' as it is designated in some instances) above a given threshold (in this case a mean monthly temperature of 42°F), over a period of time, is the method most commonly adopted for assessing the cumulative effect of temperature conditions.

PEEBLES AREA

ACCUMULATED TEMPERATURES

		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Year
PEEBLES DISTRICT	S.L.	90	248	390	496	465	360	186		2235
	500'	42	198	342	446	415	312	136		1889
	1000'		145	291	393	362	251	83		1527
	1500'		93	240	341	310	210	31		1225
	2000'		43	192	291	260	162			949
STOBO	600'	42	204	378	455	430	297	102		1910
	1000'	3	164	339	415	390	258	62		1632
	1500'		111	288	362	337	207	9		1312
	2000'		62	240	313	288	159			1062
N. ESK RES.	1150'		120	306	387	375	255	58		1503
	1500'		89	276	356	344	225	27		1319
	2000'		27	216	294	282	165			985
GALASHEILS	416'	48	198	360	461	440	309	114		1932
	1000'		136	300	399	378	249	52		1520
	1500'		89	255	353	331	204	6		1240
	2000'		43	210	306	285	159			1004
PEEBLES	765'	9	179	372	446	434	291	93		1915
	1000'		158	351	424	412	270	71		1687
	1500'		105	300	372	359	219	18		1374
	2000'		55	252	322	310	171			1111
EDINBURGH (Blackford Hill)	441'	51	213	366	486	468	342	240	3	2170
	1000'		158	312	430	412	288	130		1731
	1500'		74	251	378	359	237	77		1577
	2000'		58	216	300	313	192	31		1111

WANLOCKHEAD AREA

ACCUMULATED TEMPERATURES

		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Year
WANLOCKHEAD DISTRICT	S.L.	90	263	390	496	465	330	186		2220
	500'	42	213	342	446	415	282	136		1878
	1000'		161	291	393	362	231	83		1523
	1500'		108	240	341	310	180	31		2110
	2000'		58	192	291	260	132			934
DRUMLANRIG	120'	99	244	408	492	461	348	151		2206
	500'	60	204	369	452	421	309	111		1928
	1000'	9	151	318	399	368	258	58		1564
	1500'		102	270	350	319	210	9		1261
	2000'		49	219	297	266	159			991
DOUGLAS	783'	33	173	354	434	418	288	77		1878
	1083'	3	142	324	403	387	258	46		1590
	1500'		99	282	359	344	216	3		1304
	2000'		49	234	320	294	168			1066
LEADHILLS	1310'		136	251	381	356	204	62		1391
	2000'		34	192	310	285	135			956
WANLOCKHEAD	1334'		108	288	375	365	237	37		1411
	2000'		40	222	306	297	165			1031

NEWTON STEWART AREA

ACCUMULATED TEMPERATURES.

		Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Year
NEWTON STEWART DISTRICT	S.L.	90	279	390	496	465	360	232	45	2357
	500'	42	229	342	446	415	312	182		1970
	1000'		176	291	393	362	251	130		1625
	1500'		124	240	341	310	210	77		1302
	2000'		74	192	291	260	162	27		1008
CALEY	500'	39	201	354	427	396	285	90		1795
	1000'		148	303	375	362	234	66		1489
	1500'		102	285	328	297	189			1201
	2000'		46	204	275	244	135			906
KIRKCOWAN (B)	500'	69	210	354	452	415	324	124		1949
	1000'	15	155	300	396	359	270	37		1533
	1500'		108	255	350	313	225	21		1273
	2000'		55	204	297	260	174			991
GLENLEE (B)	500'	63	213	378	449	457	315	114		1991
	1000'	15	164	330	409	378	267	65		1628
	1500'		111	279	356	325	216	15		1304
	2000'		58	228	303	272	165			1028

Standardised methods and formulae for calculating accumulated temperatures, based on the use of daily maxima and minima, are provided in Meteorological publications[1]. In view, however, of the variable and generalised data available, a simpler method has been adopted here. The number of 'day degrees' accumulated in any one month has been obtained merely by multiplying the number of degrees by which mean monthly temperature exceeds 42°F by the number of days in any particular month. In this manner, from the reduced mean monthly temperature a series of monthly and yearly totals of accumulated temperatures for selected altitudes was obtained from the reduced mean monthly temperatures for the various stations and 'district' values within each area (see tables opposite). These results can only be approximate and above all relative values deduced from averaged instrumental records - and the amount and quality of the latter in no way justify the use of more complicated methods and formulae in their computation. The following table summarises the results of these calculations.

ACCUMULATED TEMPERATURES - ANNUAL TOTALS - IN DAY DEGREES

ALTITUDE	NEWTON STEWART		WANLOCKHEAD		PEEBLES	
	D	S	D	S	D	S
S. L.	2357	-	2220	-	2235	-
500'	1970	1991→1949	1878	1878→1928	1889	1932→1910
1000'	1625	1628→1533	1523	1590→1564	1527	1687→1503
1500'	1302	1304→1273	1200	1304→1261	1225	1374→1240
2000'	1008	1028→ 991	934	1066→ 956	949	1062→ 985

(D - based on 'district values' of mean monthly temperatures.
(S - based on groups of individual stations.

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[1] Meteorological Office (1938) pp. 5-6.

Again, the wide range of variation in the mean annual amount of accumulated temperature at any given altitude provided by the groups of individual stations makes comparison difficult. For that reason, the procedure of merely using the values from 'district' temperature averages as the basis for comparison of the three areas has once again been adopted. The mean monthly and annual totals of accumulated temperature deduced from 'district' averages have been diagrammatically illustrated (see F. 55 A and B).

From this analysis the first fact to emerge is that fundamentally the contrasts in the growing season, as between individual areas at selected altitudes, follow the same pattern as in the diagram indicating merely the length of this period (F. 55 C); but, the differences, such as exist, are greater and the contrasts more sharply defined. Decrease of the effective growing season with altitude is much more marked, and in terms, therefore, of effective heat, altitudes of 2000' have values that are representative of less than 50% (47% - 42%) of those for sea-level. Again, the "quality" of the growing season so defined reveals, in a somewhat more marked fashion, the superiority at all altitudes of the Newton Stewart over the other two areas; the values for the Wanlockhead and Peebles areas reveal a much closer approximation of growing season conditions but with nevertheless the latter area still slightly in the ascendant.

The complementary analysis of mean <u>monthly</u> values of accumulated temperature (see F. 55 A) illustrates very clearly that basically these differences as between the three areas arise, not from variations in the <u>actual</u> mean temperatures of the warmest months - which are in fact very similar in all districts - but from the temperatures of the more critical spring and autumn months. The somewhat higher mean temperature values in May particularly, and again in October and November, assures the Newton Stewart area (with its milder winter and in particular, from an agricultural standpoint, milder spring and autumn conditions) of not only a longer but a more effective growing season than in the two more easterly areas. The similarity of temperature conditions between these two latter areas is very close; but it is interesting to note that in spring (May) the Wanlockhead area appears to have slightly higher mean temperatures and consequently higher accumulated temperature values than the Peebles area which, at this period, is often exposed to unfavourable easterly influences. However, somewhat higher autumn temperatures in this latter area more than offset this difference in the early part of the year with the result that, in total, the effectiveness of the growing season in the Peebles area is slightly superior to that in the more centrally placed Wanlockhead area.

From whatever aspect, therefore, temperature values are inspected it appears to remain clearly obvious that the differences which exist between the three areas, and which have just been outlined, stem very largely from differences in winter, spring and, to perhaps a lesser extent, autumn temperature conditions. The mean monthly temperatures of the summer months are comparatively similar and it is certainly the milder winter conditions that characterise the south-western from the two more eastern areas. However, although they are hardly contrasts of a sufficiently marked degree to be reflected in peculiar types of vegetation, the milder spring and autumn conditions of the south-west allows, not only a longer vegetative period (which may or may not persist at all altitudes), but consequently a correspondingly longer grazing period for both hill and park animals in the Newton Stewart area.

Snow: The contrast in winter conditions as between the Newton Stewart area and the other two is further strengthened by the differences in the prevalence of snowfall and, in particular, the length of its duration on the ground within each of the three areas. These are indicated by the following annual averages extracted from the Climatological Atlas of the British Isles.

Average number of days with snow falling on low ground (0-200') in winter months (1912-1938).

N.S. 15-20	W.L.H. 25	P. 30

Average number of days with snow lying in winter months (1912-1938)

N.S. 10-30	W.L.H. 20-50	P. 20-50

Humidity: More important, however, in its effect on vegetation is the indirect influence which temperature exerts, by way of its determination of the humidity, on the evaporating power of the atmosphere and the consequent water loss from soil and plant. And certainly, in a relatively homogenous area such as the Southern Uplands, where between 1000'-2000' geological variations are of minor importance, the effectiveness of a given rainfall amount, conditioned by evaporation (and topography), is probably the

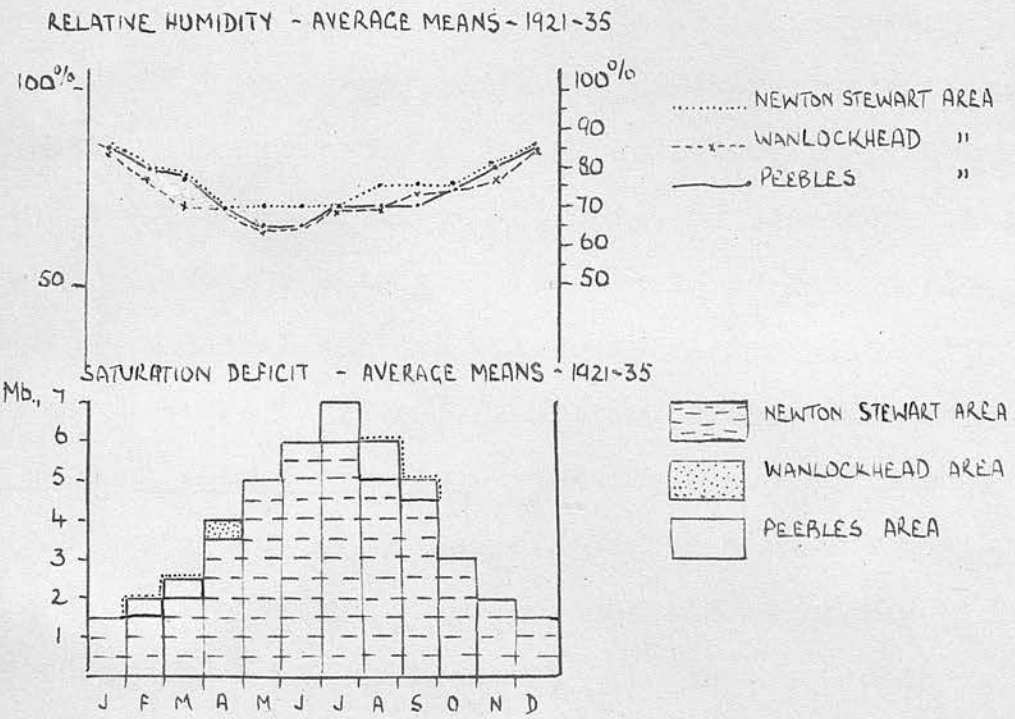
RELATIVE HUMIDITY - AVERAGE MEANS - 1921-35
100%
50
100%
90
80
70
60
50
NEWTON STEWART AREA
WANLOCKHEAD "
PEEBLES "
SATURATION DEFICIT - AVERAGE MEANS - 1921-35
Mb., 7
6
5
4
3
2
1
J F M A M J J A S O N D
NEWTON STEWART AREA
WANLOCKHEAD AREA
PEEBLES AREA

DIAGRAM 13.

dominant factor in determining soil characteristics, and some of the principal vegetation contrasts must arise from the differing moisture content of such upland soils. Atmospheric humidity and the resulting effectiveness of evaporation - fundamental expressions of the relationships existing between given rainfall and temperature conditions - are unfortunately, in view of their very considerable biological importance, not easy to define or express satisfactorily. Further, quantitative data are even more drastically limited than for other climatic elements - and the only measurements on which any reliable, albeit very generalised, comparisons can be based are the district averages provided by the Climatological Atlas of the British Isles.

The seasonal variations in the hygrometric state of the atmosphere expressed as either <u>relative humidity</u> or <u>saturation deficit</u> are summarised in Diagram 13 (opposite). For the former, monthly values as between the three areas do not deviate greatly. The greatest contrast is evidenced by the Newton Stewart area with its somewhat higher relative humidity in the summer months, an expression of its higher rainfall and slightly lower summer temperatures. In winter, early spring, and autumn there appears to be a higher degree of correspondence between the Newton Stewart and Peebles areas, while the lower values of the central, Wanlockhead area, particularly in March and November, are probably an expression of its more 'continental', inland position. The even lower value of the Peebles area in September on the other hand must be considered as probably a direct expression of the higher temperature conditions in this area at this time of the year. Saturation deficits, on the other hand, provide values which give a more precise and direct measure of the relative evaporating power of the atmosphere. Inverse in their seasonal variations to those of relative humidity, the contrasts as between the three areas revealed by deficit values are essentially similar, except for a lag in the summer and autumn months, but are somewhat more sharply defined. Once again the principal differences occur in early spring (Feburary and March) and late summer (August-September) when the Wanlockhead and Peebles areas appear to have closely similar and slightly higher deficits than the Newton Stewart area. In July, however, values for Peebles exceed those for the other two areas, while in April, Wanlockhead has this advantage - no doubt for the same reasons as in the case of the similar variations in relative humidity. For the remainder of the year, and particularly in the winter months - deficits are similarly low for all three areas.

The most, however, that these necessarily very generalised figures and diagrams can do is to corroborate and strengthen the original premise that the somewhat higher atmospheric humidity of the south-west during the summer months (at which season the potentialities for effective evaporation presented by higher temperatures may be completely annulled in this area) is a factor of some considerable importance in determining the individuality of the climate of the Newton Stewart area - and consequently its vegetation and soil types - in contrast to the two more closely related eastern areas. <u>But</u>, it is impossible to state precisely how far, <u>if</u> at all, the contrast is maintained at high altitudes, where the often persistently low cloud, the frequent hill mist, the considerable exposure to high wind force, and the lower, particularly summer, temperatures common to the bulk of all three upland areas must, even in the summer months, bring the humidity conditions of the east into line with those of the west.

Various attempts have been made by both climatologists and ecologists to define vegetation types, and their limits, in terms either of the evaporating potential of the atmosphere or of the effectiveness of a given rainfall; this had led to endeavours to express this most important and complex factor of the biological habitat as a ratio - a relationship between annual (usually) rainfall amount and the amount of water lost directly or indirectly by evaporation, the latter expressed in terms of either evaporation, temperature, or humidity conditions, according to available data. One of these attempts most relevant to this particular study is that made by Fraser in his use of the N/S (rainfall/saturation deficit) ratio as, "a simple method of expressing the combined action of rainfall and rate of evaporation" which may be expected, "to give a more satisfactory index of the kind of soil which may be developed in any region, than rainfall alone"[1]. On the basis of what must be considered very meagre data (indeed, Tansley[2] questions whether, in fact, available data

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1 Fraser, G.K., (1933) pp. 8-9.

2 Tansley, A.G., (1949a) pp. 33-34.

justifies any attempt to map P/E or P/S values for the British Isles), he has calculated the N (or P)/S ratio for the whole of the British Isles and has expressed his results in the form of an isopleth map[1].

In Britain, and particularly in Scotland, the coincidence of areas where the ratio is high (over 1000) with those of highest rainfall is not surprising; a further parallelism is postulated between areas where N/S values exceed 1000 and those where climatic moor constitutes the principal stable soil type, peat development without this area either being essentially topographical in origin or due to former climatic conditions. If the three sample areas in question are viewed in relation to Fraser's map it will be seen that while the Newton Stewart area lies wholly within the former area (N/S over 1000) and the Peebles area wholly without (N/S less than 750), the Wanlockhead area occupies a transitional, and intermediate position with most of its area within that region, which according to Fraser, has a N/S ratio of 750-1000.

The assessment however of the possible correlations which may exist between atmospheric humidity conditions, and vegetation types is fraught with difficulties arising from the lack of meteorological data and, as Tansley points out from, not only the seasonal fluctuations of rainfall and temperature, but from the consequent seasonal variations in the intensity and rate of transpiration of many plants. In view bowever of the similarity of the generally low summer temperatures and seasonal incidence of rainfall within

[1] Fraser, G.K., (1933) p. 86.

these three upland areas, Fraser's analysis, generalised as it is, does provide a fairly reasonable basis for comparison. But it is questionable whether the resulting contrasts and possible correlations which can be drawn on a basis of such a method are any more refined, or enlightening, than those revealed by a consideration of rainfall alone. In view of the low summer temperatures and further, the fact that the differences which exist in these temperatures conditions throughout the hill areas of the Southern Uplands do not appear to be of a very high order, there is much to be said in favour of assessing, as Pearsall does, the humidity of wide areas, and the possible effects of atmospheric humidity (i.e. in terms of a P/E ratio) in terms of rainfall differences alone. He postulates in Britain an annual rainfall of 50"-55" as sufficing to give humidity conditions (subject of course to topographical controls) favourable to bog (e.g. equivalent to Fraser's moorland soils) development[1]. On the basis of his criterion, practically the whole of the Newton Stewart and the Wanlockhead areas come within the limits of a 'bog-forming' climate, the Peebles area, except perhaps for the highest part of the Leithen Plateau, lying wholly without such limits.

Wind: Perhaps second only to high rainfall must severe exposure to persistently high wind force be regarded as one of the most virulent of the many adverse climatic factors with which farmers in upland areas have to contend. In its actual physical effects on vegetation, particularly on plant growth, and in its modification

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[1] Pearsall, W.H., (1950) p. 40.

of other climatic elements, by way of a tendency to increase evaporation and to decrease temperature values must wind play an important, though varying, part in the complex of climatic factors in any particular ecological habitat. Rarely can it alone be considered to determine a particular type of vegetation - but it can play a dominant role; as Tansley points, out high wind force must be regarded as one of the most important climatic factors, among others, determining the development of an artic-alpine vegetation community in Britain[1]. It is in its limiting effect on plant growth that wind exercises its greatest control and influence on vegetation.

Records of wind velocities and directions are limited, the most reliable and long term data being largely confined to coastal areas. An analysis of Buchan's averages for wind directions (see F. 56), though based on short term records during the last century, help to illustrate and corroborate for Southern Scotland the characteristic prevalence of west, south, and particularly south-west winds. The map further indicates that in certain instances (see Wanlockhead, and N. Esk Reservoir and Inveresk in the Central Lowlands) topography may play an important part in canalising and in giving pre-eminence to a particular wind direction. Exposure to prevailing winds decreases from a maximum in the Newton Stewart area eastwards. Although largely surrounded by high ground western influences can, and do, penetrate to the Wanlockhead area along the west-east part of the

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1 Tansley, A.G., (1949a) p. 43.

Nith valley where it breaches the Southern Uplands. The Peebles area must receive the maximum shelter from prevailing winds although the exposed north west facing scarp of the Moorfoots cannot be entirely free from such influences. However, as Manley reminds us, the influence of the <u>dominant</u> wind to which any area is exposed is of extreme importance. He states that, "a station on an exposed north-easterly slope will commonly give shade maxima in summer averaging 2°-3° below those at the same level in a more sheltered position; on many sunny days the difference would be likely to exceed 5°"[1]. In this respect, the east, north-east, and north winds, dominant in spring and early summer, are a notoriously well known influence in the environment particularly of the Peebles area to which it is fully exposed and which contribute to the often protracted, harsh, cold, and damp spring conditions. It is an influence which, as far as the three particular areas are concerned, must diminish westwards.

While the two 'outer areas' are, therefore, considerably exposed to prevailing and dominant winds respectively the central, Wanlockhead area, occupies a more favourable position in this respect - a fact slightly reflected in the district averages provided by the Climatological Atlas of the British Isles for

1 <u>Average wind speed (1926-40)</u>

N.S. 12.5	W.L.H. 10-12	P. 10 - 12 mph.

2 <u>Approximate average annual number of days with gale (1918-37).</u>

N.S. 10-20	W.L.H. 10	P. 10 - 20 days.

Wind speeds decrease slightly from west to east, and from 'coastal' areas inland. It must, however, be remembered also that velocities

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1 Manley, G., (1944) p. 243.

on exposed summits may be twice those over adjacent lowlands. Also, although the maximum height of the summit levels of the Southern Upland plateau occur towards the centre and south-west the variation in height is hardly great enough to provide any great degree of shelter to the eastern summits. Of the three areas, the Newton Stewart one must be considered as the most 'exposed', since the frequency of the prevailing south-westerly winds is considerably higher than for any other direction, and, on the whole, velocities must be expected to be somewhat higher at all altitudes. However, the principal contrast with regard to exposure to wind is that existing between the two 'coastal' or outer areas and the more sheltered centrally placed Wanlockhead one.

The canalising effect of topography in certain areas on prevailing and also dominant wind directions, already referred to, serves as a reminder that within any of the three areas which have been compared on the basis of largely generalised 'district' climatic averages, topography, must, and does, play an important role in differentiating "local" climates - particularly in upland areas such as these, where the contrast between deep low-lying and often narrow valleys, and high exposed summits, is probably also reflected in distinct local climates associated with these two different types of sites. In the absence of instrumental records one must needs turn more and more to vegetation (be it semi-natural or cultivated) as well as other associated features, for an indication of those local climatic differences which are conditioned by relief. Except, however, in certain well marked respects - such as to give but two examples, frost-drainage or wind-shearing - an appreciation of the nature and effects of local, as distinct from regional, climate on vegetation requires a fairly intimate knowledge of any one particular locality under all seasonal conditions - a knowledge of which local farmers and other inhabitants often have a considerable store.

The fundamental purpose, however, of the analysis presented here has been an attempt to assess, as precisely as available data will allow, the nature of the broader regional climatic differences which may be reasonably expected to exist between the three upland areas in question. For the most, it has merely served to illustrate the all to inadequate basis on which ecological workers must so often be forced to base an important part of their studies and researches, and to strengthen and re-emphasise those contrasts originally postulated between the three areas here. The latter may be finally summarised under the following headings:-

1) the principal and most striking contrast is that existing between the Newton Stewart and Peebles areas in respect of the higher annual rainfall amount, higher atmospheric humidity, milder temperature conditions, with, in particular, higher winter, and spring, and a slight suggestion of lower summer temperatures, and greater exposure to high wind force in the <u>former</u> area;

2) the essentially <u>transitional</u>, intermediate, nature of the

Wanlockhead area whose climatic characteristics are also influenced considerably by its inland, 'continental', and relatively sheltered position:

a) in its temperature and atmospheric humidity conditions it reveals certain well marked affinities with the Peebles area,

b) in its relatively high annual rainfall amount it is however, more closely related to the Newton Stewart area.

However, as has been reiterated frequently, there must be a considerable modification of the sharper regional contrasts by the influence of high altitudes which, in turn, must tend to give a closer approximation of summer temperature and humidity conditions throughout all three areas than occurs in the adjacent lowlands. From an agricultural standpoint, it is of some importance that it is the early spring conditions on which many of the most important climatic contrasts, as between the south-west and north-east hinge, - and these, together with the varying temperature and humidity conditions of summer months, must play (or have played) a dominant role in determining the principal types of moorland vegetation.

However, while we can point to climatic differences, on a regional or in some cases on a local scale, the difficulty, indeed impossibility, of defining them more precisely over small areas must persist as long as meteorological data, especially in upland areas, is lacking. This must be one of the main reasons for Tansley's observation, that no serious attempt has been made to correlate climatic factors quantitatively with the distribution of British natural or semi-natural vegetation[1]; the success of attempts which have been, and which might in the future be, made to do so, must further be jeopardised by the inescapable fact that, not only is there very little of the British vegetation which has not been subjected to long-continued and often drastic modification by man and his animals, but it seems, as far as can be judged, unlikely that the original vegetation, before modification, was in fact developed under climatic conditions similar to those pertaining at the present and within recent historic times. However, the differentiating effects of climate as far as vegetation are concerned, though ameliorated by both relief and the effect of man, are far from negligible, but in the majority of hill areas attempts to assess these effects must needs be essentially qualitative - deductive, as far as is possible, from well marked regional differences in the vegetation over a wide area or areas. In the following chapter, a comparative resumé of the vegetation of the three sample areas investigated will attempt to indicate how far the climatic contrasts recently outlined may perhaps be reflected in the present distribution of the semi-natural moorland vegetation of the Southern Uplands.

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[1] Tansley, A.G., (1949a) p. 68.

CHAPTER XIII

Vegetation: A Comparative Study.

From the Newton Stewart area in the south-west, by way of Wanlockhead to the Peebles area in the north-east of the Southern Uplands there is, as the vegetation maps indicate, a progressive increase in the percentage acreage of each area occupied by improved land of one kind or another; this increase appears to have, on the one hand, what can best be termed as an 'inverse' relationship to the actual <u>amount</u> of easily cultivable, low ground of gentle or intermediate gradient below 750'-1000' in each of the three areas, and on the other, a more positive and direct correlation with the corresponding increase in height of the altitudinal limits of such land as from south-west to north-east.... as the following figures indicate:-

	NEWTON STEWART (S.W.)	WANLOCKHEAD (C.)	PEEBLES (N.E.)
'average' altitude of upper limit of improved land	250'	750'	1000'
maximum altitude of the same	500'	1000'→1100'	1250'→1300'

And although somewhat, and of necessity, generalised, the values for the respective altitudinal limits in each area, whether the 'average' or 'maximum' figures be compared, serve to stress the fact that the essential and most fundamental difference is revealed between the Newton Stewart and the two more closely similar eastern areas. It is a contrast made even more striking by a comparison of the slope analyses (see F.17,F.28 and F.42) for each of the three areas which, further, reveals the very considerable proportion of the Newton Stewart area, in contrast to the other two, occupied by land of gentle gradient below a 1000'.

Disregarding the various and purely economic factors which may, in any region, influence the altitudes to which arable and improved pasture land are extended at any particular time - and which, for the purpose of this study, may be assumed to operate with equal intensity and effectiveness over all these upland areas of comparatively uniform land utilisation - study and comparison of the areas in relation to physical factors alone can be reasonably expected to give some indication of the inherent possibilities for arable agriculture and improvement, and the extent to which they are realised at the present time, as well as helping to explain such differences as exist between each of the three areas. The latter can be most usefully analysed by summarising first, the character of the most important climatic - temperature and rainfall - conditions at the respective altitudinal limits of the improved land.

	NEWTON STEWART area		WANLOCKHEAD area	PEEBLES area
	at 500'	at 1000'	at 1000'	at 1000+'
Average annual rainfall	45"→50"	60"	50"→55"	40"→45"
Length of growing season	5 Apr.→ 14 Nov. 223 days	17 Apr. → 1 Nov. 202 days	16 Apr. → 27 Oct. 196 days	16 Apr. → 30 Oct. 200 days
Total annual accumulated temperatures (days degrees)	1970	1625	1554	1527

This table, although based on very generalised data, points to some of those principal climatic contrasts analysed in more detail in the previous chapter, which are most important from an agricultural standpoint, as between the three areas. It has been suggested that an annual value of 1500 day degrees of accumulated temperature marks roughly the limit of cereal cultivation in Scotland[1]. It is interesting, therefore, to note that in the Peebles area improved arable land at 1000'-1250' may be regarded, on the basis of this criterion, to have practically reached its possible successful limit, and the amount by which the Wanlockhead falls short of it, though somewhat greater, is not very different from the Peebles area for the same approximate altitude. In sharp contrast however, in the Newton Stewart area at the <u>maximum</u> altitudinal limit of improved land at 500', the growing season so defined, and with annual

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1 Linton, D.L. and Snodgrass, C.P., (1946) p. 390.

accumulated temperatures of 1970 d. d. appears even more, and indeed entirely, favourable[1] for arable cereal cultivation and, that even at 1000', well above the present limits, accumulated temperature values exceed the postulated minimum for cereal cultivation in Scotland to a much greater extent than is the case at this altitude in the two eastern areas... facts that are further reflected, although to a less clearly marked degree, in a comparison of the actual length of the growing season in days at these respective limits.

On the other hand, there would appear to be a more definite and positive correlation between the altitudinal limits of improved land in each of the three areas and the probable annual rainfall amount at these altitudes. Rainfall limits determining the present approximate extent of enclosed and improved pasture have been tentatively suggested by Manley[2], for certain parts of Britain, as lying close to the 65" annual isohyet on Dartmoor, 55" in Central Wales with decreasing values in Arran, Galloway, and the Pennines, and falling to 40" in Caithness - with these variations throughout the country dependent upon the effectiveness of a given rainfall amount as determined by such inter-related factors as temperature, soil, and landforms. On the basis of annual rainfall amount alone, therefore, it is worthy of note that, within the three areas surveyed, there is a generally close

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1 Linton, D.L and Snodgrass, C.P. (1946), p. 390. " long experience has shown that approximately 1960 day degrees are required for the successful ripening of wheat at Rothamstead Hertfordshire"

2 Manley, G., (1944)

approximation between the limits of improved land, and a rainfall of 45"-55" - but with a slight decrease from west to east - while at 1000' the contrast between the Newton Stewart area with an annual rainfall of approximately 60" and the Peebles area with a maximum of 45" at this altitude, is so pronounced as to suggest that total annual rainfall may, in these upland areas, play an important part in determining the upper limits of successful improvement and cultivation.

Bearing in mind the differences in the conditions of atmospheric humidity, and evaporation, already suggested between the three areas, as well as the fact that rainfall amount may often be reasonably taken - given approximately similar temperature conditions - as a measure of the possible humidity conditions, and as a measure of the effectiveness of a given rainfall, it will be appreciated that the altitudinal limits of improved land in both the Newton Stewart and Wanlockhead areas approximates very closely to those figures (50"-55") suggested by Pearsall as indicative of a 'bog-forming' climate[1], and further, (other factors being equal) to his limit of 54" annual rainfall over which a high rate of soil leaching may be expected. Indeed it would appear to corroborate the essential truth of his statement that, "for practical purposes then, we may say that the western uplands (of Britain) above 500' lie almost wholly above the limits of a bog-forming climate, while a large proportion of the eastern uplands is below these limits"[2].

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1 See page 283.

2 Pearsall (1950) p. 43.

The low limits of cultivation, particularly in the Newton Stewart and to a slightly lesser extent in the Wanlockhead area must, if only in part, be related to their higher rainfall amounts influencing, as they do, humidity and soil conditions; added to this, the fact that with such higher rainfall and humidity conditions are often associated a low sunshine amount, frequently low and persistent cloud cover, and mist, further deterrents to the successful ripening of cereal crops and harvesting of these, and hay. Further, the probability is by no means slight that in upland areas the success of attempts to improve the pasturage and grazing value of, as yet unimproved, rough hill grazings by means of artificial drainage, ploughing, fertilising and/or reseeding, methods which might be practicable and advisable from other aspects, may be determined very largely by rainfall amount and its effectiveness.[1] The possibilities in this respect appear greater in the Peebles area, where the maximum limits for successful cereal cultivation, in terms of effective temperatures, have been fully exploited but, whose limits of improved land lie generally below that of the 'bog-forming' climate and above which - dependent of course on soil and exposure - attempts at the improvement of hill grazings might be expected to have a more reasonable measure of practical, if not necessarily economic, success - than in either the Newton Stewart or Wanlockhead areas, where the limits of cultivation are - or seem to be - more closely controlled by rainfall.

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[1] see Stapledon, R.G. (1933) on the climatic aspects of the improvement of hill land.

However the exceptionally, and generally, very low altitudinal limit of improved land in the Newton Stewart area - which in fact only occasionally reaches 500' and is more often confined below 250' - cannot be explained in terms solely of unfavourable rainfall amounts or, indeed, of climatic factors alone. Wide areas of an overall gentle gradient (less than 10°), though well, and often extensively, developed below a 1000', are not only covered by often very deep blanket-bog, overlying either bare ice-scraped rock or sticky, heavy, glacial deposits which present climatic conditions make difficult to drain or improve, but, in addition, the actual land-surface over 250', as has already been indicated, is so roughened and broken that cultivation or improvement on any reasonably sized scale would be difficult and indeed impossible, even if soil and climatic conditions were more favourable. Evidences of a former cultivation of these 'low moors', dating probably from before the decline of the black cattle droving trade and the decline of rural population during the 18th and 19th centuries, when a type of crofting economy was prevalent in these western uplands, is still visible up to 800' but always in the form of essentially very small and scattered patches of lazy-bed cultivation, restricted in extent by the limited and discontinuous nature of available favourable sites. Further, this often excessive ridging and gouging of the land surface has resulted in enclosed depressions occupied by frequently great depths of intractable peat which, as the Forestry Commission has discovered to their cost, are practically impossible to drain effectively. Finally, although the percentage acreage below 1000' is - and particularly of easily cultivable sites - on the whole greater in the Wanlockhead than in the Peebles area the generally more favourable climatic conditions expressed in terms of annual rainfall, and length and effectiveness of the growing season, plus the "shortages" of alternative available sites at low altitudes, has resulted in not only a higher altitudinal limit of cultivation in the latter area, but the occupation of slopes of such steepness that, in many cases, they must be very near their maximum as far as facility and practicability of ploughing is concerned. Also, the more extensive and continuous extent of improved land around the periphery of the Peebles area, in contrast to that of Wanlockhead, must be related to the comparable but much greater development of a general plateau level, between 1000-1250' approximately, whose broad, low, gently-sloping spurs, affording reasonable slope conditions - and some depth of mineral soil (be it derived from till, or rock weathered in situ or transported from higher levels) - provide an incentive to cultivation at relatively high altitudes in this area.

Above the limits of extensive and continuously improved land, within the three respective areas of Newton Stewart, Wanlockhead and Peebles, surveys of the much modified vegetation of the unimproved hill grazings indicate a kalaedoscopic pattern of vegetation associations, and intermingled facies, in whose general specific composition - or slightly varied combination of a few characteristic species common to all three areas - and in whose general relationship to slope conditions, and to altitude, a certain basic degree of similarity, as between the south-west and north-east of the Southern Uplands, is revealed. Probably the two most important and basic facts which emerge from the detailed study of the associations and their "facies" in each of the areas in question are, first, that the majority of those associations most easily recognised and defined, within any one area, owe their differentiation, definition, and principal characteristics <u>more</u> to modification by man than to any other factor; and second, that the distributional pattern of a given combination of associations is dependent very largely on the distributional 'pattern' of landforms (as defined mainly by conditions of slope and altitude) in any one particular area. The different 'patterns' of associations revealed by each of the three vegetation maps can be explained, broadly, in terms of relatively slight and, one might almost say, insignificant variations in the arrangement of the main landform features, and the recurrence of certain associations common to all three areas suggests a fairly close genetical relationship between the vegetation of the three areas. However, certain fundamental differences exist as between individual associations similarly represented in all areas and in their particular relationships to the other associations and to the landforms in any of the individual areas which the maps, often because of their limited scale and scope, do not necessarily reveal clearly, if at all. Further, these are differences which are not always easy to define precisely or quantitatively on the basis of a survey such as this, and which cannot always be explained in terms of the particular character of any one area alone. In the course of the analyses of the individual areas most of these differences have been referred to. At attempt will now be made to isolate what are considered to be the most important and significant of these, to indicate how far they may perhaps be considered representative of a fundamental difference and progressive change - if it can be maintained that such exists - between the vegetation of south-west and north-east of the Southern Uplands, and to consider how far it is possible on the basis solely of this essentially broad survey to explain them.

A comparison of the three vegetation maps (see F. 12, F. 33 and F. 48) reveals first, that wet moorlands occupy a considerable proportion of each area, being however most extensive and widespread in that of Newton Stewart, and that each possesses many of its principal associations in common with the others. It must probably be accepted that the bulk of the wet moorlands within all three areas is a form of, or near derivation from, blanket-bog, "the climatic climax (except where soil drainage is quite free and on exceptionally steep slopes) in regionsof cool summers, high rainfall, and very high atmospheric humidity over surfaces flat or with a slight slope (under 15°)"[1]. A further comparison of each of the three vegetation maps with the related slope analyses (see F. 17, F. 28 and F. 42) of the particular areas,

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1 Tansley, A.G., (1949a) p. 718

indicates, a close but by no means <u>exact</u>, coincidence between areas of slope under 10° and those where some form of wet moorland is predominant. However, before too much emphasis is laid on its somewhat greater and apparently more continuous extent in the Newton Stewart,area (as shown on the vegetation map) than in the other two areas, two facts must be remembered. First, that within this former area wet moorland does in fact transgress areas of steeper slope (over 10° or even 20°) largely by reason of the broken and ridged nature of such slopes - particularly where furrowing runs <u>across</u> the slope of the ground - and by impeding drainage, allows the development of wet peat, and associated species, over areas which might be regarded, on the basis of the general slope analysis, or representation on a topographical map alone, as too steep,even under the more extremely oceanic climate of the south-west,to allow the accumulation of any depth of peat. Second, the wide development of an area of gentle slope below 1000' in this particular area, together with that particular method of classifying vegetation peculiar to this area, suggests a more compact and <u>continuous</u> development of wet moorland than is in fact the case. Again, the intensely roughened and broken land surface, both above and below a 1000', results in a much greater and more detailed small-scale interpenetration of wet and dry moorland associations than the map can adequately illustrate. And, certainly, the definition as between areas of wet and dry moorland is not so clear cut as in the more uniform areas further east. There is, however, a suggestion borne out, if only very generally, by the few slope measurements attempted in the Newton Stewart area, but based largely on general observations, that wet moorland, particularly of the more mixed varieties, occurs in some cases over slopes of steeper gradient than further east. However, more obvious is the fact that in the Wanlockhead, and more particularly in the Peebles area, spreads of wet moorland are frequently much less extensive than the actual areas of gentle slope, so defined, over which they normally occur. Also, the relatively small and scattered development of plateau - like surfaces of gentle slope over 1500' in the Newton Stewart area, together with the ridging of the land surface, has not favoured the establishment of the continuously compact peat caps at high levels which are such a conspicuous feature of the two eastern areas.

How far, however, are the areas of wet moorland which, in one form or another, 'blanket' areas of gentle slope from south-west to north-east - from sea level upwards in the south-west, but more generally above a 1000' in the other areas - to be considered an expression of existing climatic conditions? The difficulty of answering this question stems, as has already been intimated, from the fact that not only are the data necessary to verify the validity of such a correlation not available, but also from a degree of uncertainty as to the exact nature of absolutely natural and unmodified blanket-bog vegetation in these particular areas. All the wet moorland, of one kind or another, up to at least 1750', and often over 2000', in the eastern areas bear the evidence of frequently far advanced modification by natural or "artificial" agencies - which, over a period of time, must have tended to alter the balance, and ratio, of the constituent species, as well as to modify the physical and chemical composition of the underlying peat accumulations associated with the original blanket bog. The tendency over all three areas (other factors being equal) would under such influences appear to be towards increasing dryness as evidenced by the combination of species now dominant on such areas. No detailed investigation of the stratification and composition of the peat deposits of the Southern Uplands has been undertaken, as far as is known, since F.J. Lewis published his studies of Scottish Peat Mosses in 1905-6[1]. However, the general results and implications of his findings have largely been but corroborated and elaborated by the more refined methods of peat and pollen analysis, in other parts of Britain. In both the Merrick Kells region at 1000' (north of the Newton Stewart area) and on the Moorfoot Hills at 1500' to 1700', his findings suggest that the upper layers of thick peat deposits are composed of plant remains indicative of a higher and more concentrated proportion of wet species (e.g. Scirpus caespitosus and Sphagnum spp.,) than occur in the present vegetation now growing on this peat - an indication that it may originally have accumulated under wetter conditions than prevail at present (or to be more precise, when Lewis actually investigated these districts).

The point, however, that still remains unsolved is whether the

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1 F.J. Lewis, (1905-6).

present signs of desiccation are a result of a recent amelioration of the original oceanic sub-Atlantic climate, under which these blanket-bogs were presumably initiated (and which, as far as rainfall and humidity conditions are concerned must be expected to have been a more drastic amelioration in the east than in the west of Scotland), intensified by natural or human modifications, or due solely to these latter causes. Pearsall puts the problem in a nutshell when he remarks that, "... it is very hard to decide by direct observation to-day between two divergent views which are frequently held. Some observers think that a peat bog starts, grows to maturity and ultimately degenerates. Thus the peat must finally reach a dissected condition no matter which of the three methods of degeneration described above (i.e. headward stream erosion, natural drainage systems of peat areas themselves, or 'bog-flows') develops first. The alternative view is that peat dissection has resulted from some form of drying, either as a result of climatic change or as a result of burning and drainage influenced as well, of course, by the natural tendency of every stream to cut back into its gathering grounds. Both views doubtless contain a considerable measure of truth, but the former one perhaps helps best to explain the enormous amount of peat erosion which can be seen in the wetter, blanket-bog parts of Britain, while the after-effects of drying the peat surface might be expected to be more pronounced in the drier eastern uplands"[1].

On the basis of Fraser's N/S ratio[2], only in the Newton

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[1] Pearsall, W.H., (1950) p. 205.

[2] See page 281

Stewart area in the south-west can wet moorland be considered a climax under existing climatic conditions; in terms of rainfall alone however both the Wanlockhead and Newton Stewart areas may be considered to possess a potential bog-forming climate[1]. Defined in such terms, it would seem that there are grounds for regarding the considerable peat caps of the drier Peebles area and probably also of parts of the transitional Wanlockhead area, "as a relic", as Tansley suggests, "of conditions introduced by the Pleistocene ice age"[2]. This might be taken as a suggestion of climatic amelioration (and particularly of decreased rainfall in the east), but, since a precise definition of what is to be considered as a 'bog-forming' climate must be somewhat arbitary, and since these attempted correlations are and have, of necessity, to be based on very limited data, it cannot be regarded by any means as conclusive evidence. Personal observation certainly corroborates the fact that the "wetness" of the south-west - and particularly of the wet moorlands - is a reality which separates the west from the east, and the much higher proportion of heather which the wet moorlands of the eastern areas carry is but one indication of this difference; also erosion and dissection of peat areas and their consequent effects on the vegetation are more advanced in the two eastern areas. Indeed, whether there has been a climatic change or not, is it reasonable, as Pearsall suggests, to expect natural and artificial modifications over the period of

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1 See page 283.

2 Tansley, A.G., (1949a) p. 719.

historic time, to have had a more drastic effect in the climatically drier east than in the wetter west .... and, it is further reasonable to assume that the existing climatic differences as between the south-west and the north-east of the Southern Uplands may influence, or have influenced, the course of such modifications, and to be, in some manner, reflected in the resulting types of vegetation.

But, however, even if we assume - as far as evidence will allow - for the purpose of comparison, that the wet moorlands in all three areas had a common, and basically similar, origin and development as blanket-bog, the subsequent modifications arising from varying <u>intensities</u> of natural, and particularly of biotic, factors over a long period of time, and acting on a diversity of physical sites or habitats necessitates some caution in a more detailed comparison of the individual associations. "Thus there are", if one may again quote Pearsall, " obviously large differences as between different parts of the uplands which are due to the varying intensity of human occupation and exploitation. Indeed it is not too much to say that the differences between one part of the Highland Zone and another from this cause are probably greater than those induced by any other factors. It would be very interesting if we could develop this idea and arrange our forms of upland vegetation in such a way as to represent the degree of human interference they indicate"[1].

A study of the various associations of the wet moorlands of these three particular areas of the Southern Uplands - (and more

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1 Pearsall, W.H., (1950) p. 208.

particularly of those of Wanlockhead and Peebles) - and of their relationships one to another, together with the modification each has undergone and to which each is still subjected, suggests <u>very</u> forcibly that most of them are indeed an expression first and foremost of just such human interference; and that further, the differentiation of the individual wet associations one from another, in any one area, <u>must</u> be considered a result mainly of varying intensities of biotic modification. The table opposite (see Diagram 14 - opposite), in summarising the generally recognisable altitudinal ranges of the wet moorland associations in each area, serves to stress what the individual area analyses in Sections II, III, IV have tended to reveal and bear out - that the broad altitudinal zonation of these associations is related directly - as must be expected - to a general decrease in intensity of interference and modification (past and present) with increasing height above the limits of improved and cultivated land, and the resulting decrease in ease of accessibility by both man and his animals. In view, however, of the fact that throughout any one area the intensity of human interference cannot be expected to be maintained to the same degree at any given altitude it is not surprising, therefore, that the altitudinal range of any association within any one area may be and, indeed, often is wide and fluctuating, and in a general summary, such as is given here in Diagram 14, to show an often considerable degree of overlap with either that above or below it. However, it should be stressed that it is a concept more readily demonstrated in, and applicable to, the two eastern than to the Newton Stewart area where, in view of the very complex and diverse nature of the moorland vegetation, (complexities often intensified by, and related to, the peculiar nature of the land surface) it has not been possible to understand or define so clearly the relationship of one association to another.

However, it is certainly a concept which must be accorded serious and pre-eminent consideration before any attempt is made to relate types of vegetation <u>directly</u> to any well defined physical habitat; also, it can and does, - indeed one might go so far as to say that it is the only reasonable one which, provides a common and logical basis, and a starting point, from which any useful comparisons between the different areas, as here, can be safely attempted. In view of what can, therefore, be regarded as an encroachment, increasing eastwards of the cultivated land and consequently of man's 'sphere of influence' over the hill-land, it might be postulated that the intensity of human interference increases also from the Newton Stewart to the Peebles area, and <u>may</u> further, be aggravated by recent climatic changes. Under such circumstances, and assuming that the various modifying agencies act within and are conditioned by a given set of physical factors defined by climatic features, particularly rainfall, whose effectiveness are often determined, or in part controlled, by landform, it is not unreasonable to expect that the broader regional differences of climate may well be revealed in the more detailed specific character of the otherwise very closely related associations.

The first fact to emerge from a comparison of the general botanical composition of the wet moorland vegetation of the three areas, in terms of the most prevalent species, and irrespective of well defined associations, is that the wet moorlands of Wanlockhead and Peebles, with Eriophorum as the most characteristic component accompanied by Scirpus, and a relatively large proportion of heather, have very close affinities, and together stand in contrast to the Newton Stewart area where such species as Molinia, Scirpus and Myrica gale predominate, with sub-ordinate heather and very little Eriophorum. This is a contrast which may reflect and be representative of two of Pearsall's 'climatically' defined types of bog, the former areas representative of his Stainmore type (rainfall 55" per annum) in which cottongrass, cross-leaved heath, and heather are predominant and the latter, of his intermediate Western Highland type (rainfall 70-75" per annum) where both Scirpus and Molinia are more usually prominent[1]. The differences are similarly reflective of Fraser's classification of the moorland vegetation into firstly, Calluna moor in the north-east, and Scirpus moor in the west and north-west of Scotland[2]. However the abundance and prevalence of Molinia throughout the wet moorland vegetation of the Wanlockhead area and also, the existence here of a well defined association dominated, often to the exclusion of all other plants, by this species must tend to relate this area to that of the south-west, and suggest what may be regarded as the essentially transitional

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1 Pearsall, W.H., (1950) pp. 150-151.

2 Fraser, G.K., (1933) pp. 9-10.

or intermediate character of its wet moorland vegetation between those principal 'climatic' types indicated by Pearsall and Fraser. How far then are possible climatic differences also revealed in the individual associations?

Considering first the two more closely and obviously related eastern areas of Wanlockhead and Peebles - if it is assumed (as it seems reasonable to do so) that the altitudinal zonation, hagged peat - mixed wet moor - Eriophorum moor - Molinia (or Nardus) moor, represents an ever-increasing intensity of modification of the original blanket-peat cap due to the increasing accessibility of successively lower levels to the interference of man and his animals, combined also with the effect of peat erosion and downwash from successively higher levels - the close similarity in the zonation and altitudinal ranges of the wet associations in these two areas is not altogether surprising. The hagged peat association probably occupies the thickest remnant of the original blanket-bog least modified by man but, nevertheless, revealing much more strikingly than elsewhere evidences of considerable modification by the agencies of <u>natural</u> erosion and dissection (due either to progressive headward erosion of streams and even artificial drainage channels, to the development of an independent and often subterranean drainage system within the peat itself or, particularly around its margins, to minor slumping). These modifications have attained striking proportions around the margins of the peat caps in the Peebles area, whose central and least modified parts, (often dominated by Scirpus, with or without Eriophorum, accompanied by abundant Sphagnum, and where peat pools are frequent in which water has accumulated in natural depressions), must be considered the nearest approach to the original conditions of the blanket-bog in these eastern areas. In both areas, the lower limit of this association is generally between 1700'-1750'; the greater upper range to 2000'+, and its wider development in the Peebles area is an expression primarily of the much greater development in this area of high lying surfaces of gentle slope between 1750'-2000'+ than in the Wanlockhead area. On the narrower and more limited summits over 2000' in this latter area, hagged peat is replaced by summit vegetation. Whether this has always been the case or whether a pre-existing peat cap of short-lived duration was formerally stripped off, because of the greater height and exposure of such summits, is questionable. It is, however, interesting to note, in comparison, that in the Peebles area the highest summits over 2000' often carry only a relatively thin peat layer, generally considerably hagged and where, in places, it has actually been eroded away, it has been replaced by a vegetation very similar in its form and composition to the summit vegetation of the western areas.

The "centrally" situated group of mixed wet moors with its closely related, and highly modified, margin of Eriophorum moor covers an even wider range of altitudes, extending over surfaces of gentle slope from 1200'-1250', close to the upper limits of cultivation, up to 1500'-1750', in both areas. It may represent either, the much depleted remnant, outliers of the original blanket-bog at lower altitudes, or be formed, in part or in whole, of peat eroded and redeposited from higher levels. To-day, it is within this group of wet moorlands, in both the Wanlockhead and Peebles areas, that evidences of man's direct interference and modification by cutting, draining, grazing, and burning are most strikingly concentrated, and where obvious modifications by natural agencies are much less apparent than in the hagged peat association. Its extent in the Wanlockhead area is on the whole greater, largely owing to the fact that in this area surfaces of gentle slope particularly between 1400'-1600' are more widely developed than in the Peebles area. The most important contrast, however, in this group of associations as between the two areas, is considered to lie in the fact that, although in both areas the mixed wet moor is essentially composed of a mixture of Eriophorum, Scirpus and Calluna, in the Wanlockhead area Molinia caerulea is nearly always present in a conspicuous quantity and also, whether abundant or merely frequent, is usually a <u>characteristic</u> member; in the Peebles area, however, this species rarely plays such a conspicuous part, if at all, in the mixed wet moor and it is, at most, usually confined by favourable slope and soil-moisture conditions to a relatively narrow zone peripheral to this association[1].

The junction between mixed wet (and indeed all other types of wet moorland) and dry moorland, as already indicated, is not always a well defined one coinciding with a well marked physical

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1 See Section IV. p.229.

boundary. Further, in the lower north-western and north-eastern parts of the Wanlockhead and Peebles areas respectively, the coincidence between spreads of wet moor and areas of gentle slope is not always absolutely complete and mutually inclusive, especially around the outer margins of such areas - and there are often quite extensive areas of gentle, or intermediate, slope which may support either an intermediate or a dry moorland vegetation. It is perhaps, in many such cases, reasonable to assume that if blanket-bog in one form or another was in fact formerly more widespread, that, under the influence of prolonged modification, such intermediate or dry moorlands on relatively gentle slopes may have been derived by the erosion and removal, or the very drastic alteration, of the originally deep wetter peat formerly existant at these lower altitudes. It has already been indicated[1] that strong evidence of what is suspected to be a deep-seated and radical alteration in the physical and biological character of the peat around those most intensely modified margins of either mixed wet and Eriophorum moor, or of hagged peat, is indicated by the presence of, what have been termed here, intermediate or "marginal" associations.

In the Wanlockhead area such changes appear to be represented by tufted Molinia moor often accompanied by abundant Polytrichum commune, Molinia and heather, or Molinia and dry grass under progressively drier conditions. It is also worthy of note that pure Molinia moor is most strongly and extensively developed in the western part of this area. Under

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1 See Section III p.166. : Section IV p.226

very similar conditions of relationship to the principal peat areas, and under very similar degrees of slope, the association suggestive of the most advanced stages of peat decomposition in the Peebles area is pure tufted Nardus moor and/or, though only to a very limited extent over somewhat restricted areas where moisture conditions are for one reason or another favourably higher, Nardus and Molinia in equal proportions. Only on those very steep slopes directly below the small areas of hagged peat, on the south eastern flanks of the Lowther Hills, is there any suggestion of a well-developed Nardus zone in the Wanlockhead area comparable to that in the Peebles area. Recalling the habitat requirements and probable status of these two species, it is tempting to infer that over those highly, naturally or artificially, modified peat margins the predominance of either Molinia or Nardus may be directly or indirectly related (other factors- especially slope conditions and the intensity of interference and modification - being equal) to such differences in annual rainfall amount as do in fact occur between these two area. This tentative correlation has been prompted largely by the results of Fenton's work, already outlined, on the developmental stages of peat decomposition and the factors affecting it[1]. However, at this stage, and in view of the particular limitations of these surveys, it must be regarded rather as an interesting and pertinent question worthy of further examination. How far any satisfactory degree of correlation could be established is debateable in view, not only of the variable nature and occurrence

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1 See Section III p. 164 et seq.,

of Molinia caerulea, but of the many imponderable factors involved.

Turning now to a comparison of the wet moorland associations of these two closely related areas with those of the Newton Stewart area in the south-west, the contrast is more striking and definite. Although the three principal associations of the Newton Stewart area - Scirpus moor, mixed wet moor, and Molinia moor - reveal altitudinal relationships one to another largely comparable to those in the two eastern areas, for various reasons, already outlined[1], they cannot necessarily always be regarded as exactly comparable counterparts of the principal altitudinal groups in the two eastern areas.

In the Newton Stewart area Scirpus moor, most prevalent over those high surfaces of gentle slope between 1500'/1700'-1900', is the association least modified either by natural or artificial agencies. The poor development of plateau-like summits over 1900'-2000', together with the severe exposure to wind of such areas as do exist, limits its development to a maximum altitude of about 1900'. Dominated mainly by Scirpus caespitosus with both Sphagnum spp., and Erica tetralix abundant, and with modifications, apart from limited grazing, evident only in a slight hagging at lower levels by the headward erosion of small burns (of but minor significance as compared with the peat hags of the east), it may well represent under the much higher rainfall conditions of the south-west (usually over 70" per annum) that

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1 See p. 300.

even less modified form of blanket-bog from which the eastern hagged peat, which in its occasional complete dominance of S. caespitosus it does in part resemble, may formerly have been derived. Scirpus moor, however, does not form as an extensive a peat cap as does the hagged peat association in the east, since the broken and often heavily ridged nature of the land surface gives rise to steeper, better drained slopes which break its continuity.

A comparison of the mixed wet moor association of the Newton Stewart area with that of the same name in the Wanlockhead and Peebles area is rendered somewhat difficult by the composite nature of the former association, a direct reflection, as it is, of the peculiar character of the land surface over which it occurs. That "facies" however of this composite association which, in its specific composition, comes closest to the mixed wet moor of Wanlockhead and Peebles is that which often becomes widespread over areas of gentle and intermediate slope from about 1000'/1200' to 1500', and which is co-dominated by an equal and diffuse mixture of Molinia-Scirpus-Calluna. It has, however, not been subjected to the same degree or variety of modifications as the mixed wet moor association of the eastern areas; also, it appears to occur over a slightly thinner layer of peat on which Sphagnum may or may not be present and over slopes of somewhat steeper gradient than are commonly associated with mixed wet moor in the east. It has not been found possible to establish with any certainty its relationship to the erstwhile climax, Scirpus moor or yet, to decide whether it represents, in part or in its entirety, an essentially developmental stage, according to Fraser[1], in the progression towards and eventual extension of a moorland climax, or whether it must be regarded as a transitional stage derived primarily by burning, from a former climax, as advocated by Anderson[2]. The evidence is conflicting, though the final answer probably lies in the operation of both factors, In the virtual absence of Eriophorum, it differs from the mixed wet moor of the two eastern areas, while in the presence of Molinia as one of its co-dominants it has certain affinities with that of the Wanlockhead area. Its significance in this latter respect is not altogether obvious and in view of its questionable status one must hesitate before ascribing the greater abundance of Molinia - indeed its co-dominance - in this association, to the higher rainfall of the south-west alone.

Finally, in the considerable development of a Molinia-dominated association (or associations as the case actually is in fact) occurring at lower altitudes - usually below a 1000' and peripheral to the main mass of the wet moorland, the Newton Stewart area reveals further, certain resemblances with the wet moorlands of Wanlockhead. A very fundamental difference, however, is provided by the fact that the Molinia 'flow' of the south-west is characteristically accompanied by Myrica gale, a species which, as far as is known, never occurs in the latter eastern area.

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1 Fraser, G.K., (1933) p. 21 : see Section II p. 90.

2 Anderson, M.L., (1950) p. 41 : see Section II p. 90.

But beyond these, largely superficial, observations the difficulty of attempting further comparisons or contrasts is aggravated by the fact that there appear to be certain radical differences in the status of the Molinia-dominated association in the Wanlockhead and Newton Stewart areas respectively. In the former area pure tufted Molinia often accompanied only by Polytrichum commune and occurring most frequently on thick, though not over-wet, amorphous, peat or peaty soil appears to be indicative of an advanced stage of peat metamorphism at the lower, highly modified, margins of the main peat blanket; in this condition, it occupies frequently a characteristic site on gently-sloping, plateau-like surfaces from 1000'-1250' on which it is subject to a continual but probably, in view of prevailing gradients, gentle flushing by the downwash of peaty water from above. On the other hand, in the latter area, the purest form of tufted Molinia accompanied usually only by Myrica gale and Juncus articulatus, on deep very wet and almost liquid peat, appears to represent an unmodified natural condition associated, under the high rainfall of Galloway, with those characteristic sites provided by flat-floored steep-sided valleys and depressions where, under optimum 'flushed' conditions, it has attained, if only temporarily, a state of stability. The nearest equivalent to these peculiar site conditions in the Wanlockhead area occur over those gently sloping floors of the few deeper, slightly U-shaped, valleys on the south-east side of the Lowther Hills. Here tufted Molinia, with often abundant Eriophorum, occupies deep peat overlying spreads of glacial material .... and, under the somewhat lower rainfall conditions of this area, the associations has probably been established and encouraged by the artificial drainage of a more mixed association tending probably to increase the flushed conditions prevalent at the base of such valley slopes.

However, there is a "facies" of the Molinia dominated moorland which, with certain minor differences, in some respects may perhaps be considered to have had a somewhat comparable derivation, and exhibit a comparable status, in the two areas. This, in the Newton Stewart area is the more mixed Molinia flow where, although this species is abundant, it is accompanied by a greater variety of other species including, as well as Myrica gale and Juncus articulatus, Sphagnum spp. , Erica tetralix, Narthecium ossifragum, Scirpus caespitosus, and occasionally Calluna vulgaris. Bearing evidence of fairly recent modification by cutting, and more particularly by drainage, to which interference it may owe its present characteristics, it is in some ways comparable to those extensively drained areas in the Wanlockhead area which often carry an association rather wetter and less intensely modified than the <u>pure</u> tufted Molinia with Polytrichum, and having a greater number of associated species, such as Sphagnum spp. , Erica tetralix S. caespitosus, Eriophorum vaginatum and Juncus spp. ,. It might be suggested that under the higher rainfall conditions of Wanlockhead and Newton Stewart, as compared with the Peebles area artificial drainage may not be so effective and drastic as further east and may be responsible for the pre-dominance of Molinia rather than Calluna on drained peat, and particularly where, at lower altitudes, physical conditions allow considerable and rapid flushing. The essential and indeed striking differences which have just been indicated between the Molinia dominated association in the Newton Stewart and Wanlockhead areas respectively, must also be regarded as primarily climatic in origin and be related to the fact that while, in the former area, a Molinia/Myrica gale association is <u>characteristic</u> of a bog-vegetation typical of the wetter western regions of Britain and often, as Pearsall suggests, of those common at lower altitudes (below 1000') which have undergone relatively recent modification; in the latter area, the Molinia dominated moorland is <u>generally</u> representative of the most highly modified margins of a peat mass that has probably been undergoing more drastic modification by both natural and artificial agencies for a greater length of time. Both associations are subjected to flushing from above, but in general, (and with few exceptions) this appears to have a relatively greater effect under the highest rainfall conditions of the Newton Stewart area, and under the particular site conditions provided by the glaciated valleys.

Lastly, it is perhaps worthy of note that Molinia caerulea, either as dominant or characteristic member of a wet, dry, or intermediate moorland association is, in both the Newton Stewart and Wanlockhead areas most prevalent and conspicuous over those sites where spreads of boulder clay (till) are most widespread as for instance, along the floors of the glaciated valleys in the former and over areas of gentle slope in the western and north-western part of the latter area. This may merely be a fortuious coincidence related to the prevalence of glacial deposits within those particular sites which promote, or under artificial drainage favour, the constant movement of abundant water. On the other hand, the presence of boulder clay (particularly if the clay content is high) must tend to insure the retention of a greater amount of soil moisture than might normally occur were it absent and, hence favour and encourage, under certain circumstances, the growth of Molinia in some quantity.

In all three areas, the development of dry moorland associations is dependent upon a combination of those factors which, in these upland regions of low temperatures and generous rainfall, prevent, or in the past prevented, the accumulation of deep, raw peat. Throughout the three areas, where superficial deposits are of minor importance and a general uniformity of rock type prevails, the close correspondence between areas of dry moorland and those, as indicated on the slope analysis maps (see F. 17, F. 28, and F. 42), whose gradient exceeds at least 10° is not unexpected; while the actual extent of such moorland, in any of the three areas, is dependent on the percentage area occupied by such slopes. There is, however, one of the associations which has been classified within the dry moorland community which must owe its establishment primarily to climatic factors - summit vegetation, or as it is often designated by other authors, summit heath[1]. It is the only definite representative of a relatively unmodified climax in the Southern Uplands which owes its form and, to a lesser extent, its specific content, and its related habitat on high summit ridges and plateaus over 2000' and 2250' in the Newton Stewart and Wanlockhead areas respectively, to a complex of climatic factors of which considerable exposure to high wind-force must be regarded as the dominant and most important. It is certainly the factor which must be principally responsible for the relatively low altitude of 2000' at which the summit vegetation makes it appearance in the south-west, an altitude somewhat higher in the centrally placed and less exposed Wanlockhead area. Its virtual absence, in any definitely recognisable or mappable form, in the Peebles area must be attributed to the fact that few parts of this area exceed 2000' to any extent and such as do, are for the most part still covered by a thick blanket of peat - though there are signs that the latter, under its present drier, and drying, condition on these high exposed areas, is susceptible to wind erosion.

Below 2000' approximately, and down to the limits of cultivated and improved land, dry moorland, represented by either a heather or a grass-dominated association, is closely related to steep, well drained and usually, and indeed primarily, smooth slopes; however, as in the case of the wet moorlands, and for

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[1] See Pearsall, W.H., (1950) p. 89.

much the same reasons, the correlation between dry moorland and steep slopes over 10° is much closer in the two eastern than over the steep but often broken slopes of the Newton Stewart area. Indeed, its somewhat greater predominance in these two former areas is as much a reflection of their favourable landforms as of their drier climates, particularly of the Peebles area; and also, the greater prevalence of wide stretches of pure, short Calluna must be related to a somewhat more systematic management, and particularly burning, for grouse as well as for sheep, over more widespread areas in this latter in contrast to the Wanlockhead area. On the other hand, while Molinia caerulea is frequently a member of this dry heather association in the Wanlockhead area, Nardus stricta and Erica cinerea occur more abundantly throughout it in the Peebles area. Also Vaccinium myrtillus either as a member, or forming a sub-association or "facies", of this association is much more frequent and widespread in the latter than in the former area, where its dominance is more local and it only becomes abundant on exceptionally steep slopes. Such slight variations in the specific content of dry heather moorlands as between the two eastern areas may be regarded as indicative of the considerably drier conditions of the Peebles area, particularly in so far as the latter effect the modification and resulting balance of species in the heather moorland areas. In contrast, in the wetter Newton Stewart areas, dry heather moorland rarely plays a conspicuous or widespread role, and, being confined to the steepest of slopes, occurs rather in scattered discontinuous patches over this essentially roughened and broken land surface. Also, not so rigorously burned or grazed, it is inclined to be long and leggy, and more often accompanied by wet species, particularly Molinia and Scirpus, than in the eastern areas.

Most, if not all, the dry grass moorlands within these three areas must further be regarded as having been derived at one time or another from a former dry heather cover by the combined effects of overgrazing and over-burning and to-day, in all three areas, it is, on the whole, not only somewhat more prevalent but is, by way of the 'patchy' mixture of grass and heather, rapidly extending its domaine at the expense of the existing dry heather. A decrease in the amount of available winter feed for hill sheep is probably one of the most serious aspects of this progressive alteration in the content of the dry heather moorland where, on the lower more favourable slopes, a weakening of the heather component and the peat layer associated with it, has favoured and encouraged the establishment and extension of bracken, resulting in what often amounts to a virtual sterilisation of the grazing value of large parts of the hill land.

Botanically, the dry grass moorland is essentially similar in each of the three areas under consideration but the greater amount of Molinia caerulea and Anthoxanthum odoratum in that of the Newton Stewart and Wanlockhead areas (in the latter however, only where slopes are not excessively steep) in contrast to the higher proportion of Nardus and fine-leaved Fescues in the Peebles area, together with the fact that the peaty component of the soil associated with the dry grass moorlands is somewhat higher and more conspicuous in the two former than in the latter area, may be considered as yet a further reflection of the differing annual rainfall amounts particularly as between the wetter Newton Stewart and Wanlockhead areas and the much drier Peebles area. However, on its exceptionally steep slopes, such as those of the Lowther Hills, the Wanlockhead area shares with that of Peebles the prevalence of an often close cropped 'sward' of fine leaved Fescues, accompanied by Vaccinium myrtillus, overlying mineral soil in which the peaty layer is thin or absent, and which is often exposed where the vegetation cover has been broken by the intense depredations of both rabbits and sheep.

The compact block of dry grass on the steeper smooth slopes of the Cambrick-Lamachan-Larg knot of central hills in the south-west has a counterpart in those high, even smoother and steeper, grass covered slopes of the Lowther Hills, south of Wanlockhead. In both cases the concentration and predominance of a grass association must be related to the absence of a peat cap and the lack of consequent downwash of peaty soil from above which would favour heather or Nardus and where, instead, a destruction of the pre-existing heather content of the vegetation has been followed by the establishment under favourable rainfall and slope conditions by a relatively varied mixture of the better grasses. Comparable conditions, dependent so largely on localised peculiarities of landform do not exist in the Peebles area. Here, and elsewhere in the Wanlockhead area, grass moorland occupies a zone of 'middle slopes' below the caps of wet moorland and above the bracken-dominated lower slopes; the frequent prevalence of Molinia on a soil of rich peaty content, particularly noticeable in the <u>western</u> half of the Wanlockhead area, suggests a well marked difference between the moisture content of the dry grass moorlands of this area and the Peebles area - a difference which again must be directly related to a difference of 10"-20" in the annual rainfall amounts of these two areas.

Finally, the contrast as between the greater modification and erosion of the wet moorlands, already indicated, in the two eastern as compared with the south western area, is repeated again in the often serious in-roads that have been made into the dry moorland vegetation of the Wanlockhead and Peebles areas. In-roads brought about by the destruction of their usually thin peaty layer, and by subsequent soil erosion, resulting from drastic modific-ations initiated by injudicuous burning and grazing under often unfavourable physical conditions (particularly steepness of slope, dryness of climate and prevalence of spring droughts), all of which serve to aggravate, and to intensify the destructive results of such modifications. As has already been indicated, vegetation destruction followed by soil and slope erosion depends, in any one particular spot, in any of the three areas, on such a complex of factors, any of which may vary in intensity and effect, not only from place to place, but from time to time, that it is difficult to venture any useful comparison as to their effects and

and results in the Wanlockhead and Peebles areas. In both, there is widespread evidence of fairly recent and often pronounced headward erosion of burns and rivers cutting deep raw gullies into hillsides above; this may be the outcome of the prolonged drainage of the main peat areas, together with peat and soil erosion on surrounding slopes, promoting more rapid run-off of rainfall and, consequently, more active erosion and dissection by the youthful head streams. Similarly, there is at times quite alarming erosion of other and, usually, excessively, steep slopes in both areas; in this respect there is some suggestion of a difference as between Wanlockhead and Peebles areas. In the former, the final result of vegetation destruction and erosion appears to commonly take the form of slope gullying, while in the latter area (where it might be said that rabbits are (or were) perhaps a more serious menace in aggravating erosion) the end-product of erosion more often takes the form of fine angular screes which fan down-slope from affected parts and eliminate the grazings of wide areas of the steepest slopes. This difference might reasonably be attributed to the higher rainfall and probably more drastically concentrated run-off on the Lowther Hills, (where the worst affected slopes in the Wanlockhead area occur) with 70" per annum, in contrast to the lower rainfall amount of 40-45" on the Moorfoots. In both areas, however, there is every reason to believe that serious slope and soil destruction has arisen by reason of what has, perhaps unwittingly, been an over drastic drainage of the wet peat moorlands above. Time and time again, it was noted that deep, raw V-shaped gullies, cutting the whole length, and deeply into, a valley-side slope, had their source at the terminus of an, often deeply eroded, artificial drainage channel and were extending their courses by way of such channels into the heart of the peat areas. This tendency is, more-over, aggravated where an artificial drainage channel terminates at the brow of a plateau or summit ridge above an exceptionally steep slope. The writer is very much of the opinion that, in view of the tendency to increased rapidity of run-off with its concomitant of often drastic flooding at lower levels after exceptionally heavy rains, to increased dryness resulting eventually in a less mixed, and often less valuable grazing content of, the vegetation, and to aggravated, under certain circumstances, slope erosion, the possibility that much of the wet moorland areas may be over-drained, or merely improperly drained, is a question that merits more serious consideration than the scope of this particular study can afford it. Peat wastage and slope erosion is not, however, so serious a problem in the Newton Stewart area though, nevertheless, the proportion of bare and cliff-like rock surfaces is very much higher than in the other areas, as a result of the more drastic effects of glacial erosion in this area. And, while scree-covered slopes are not unknown, they occur most frequently on over-steepened slopes and are generated usually by the natural weathering of bare often steep rock exposures at higher levels.

In the concluding paragraphs of each of individual area analysis an attempt was made, as far as possible, to consider the principal habitat requirements of bracken ~~made as far as possible to consider the principal habitat requirements of bracken~~ in relation to the zone in which it is most abundant in each of the three areas. In two respects only can it be said, on the basis of this particular survey, that a comparative appraisal of this plant reveals contrasts which may, in any way, be correlated with, or reflect, contrasts in habitats as provided by these three areas, representative of the Southern Uplands. First, its upper altitudinal limit of growth of usually about 800', and with a maximum rarely exceeding a 1000' in the Newton Stewart area, in contrast to an average upper limit of 1200'-1250' in the Wanlockhead and Peebles areas with a maximum in places of as much as 1500', particularly in those sheltered cleuchs provided by the deep, enclosed valleys of these two latter areas, would appear, in view of the fact that bracken seems to require some degree of shelter for vigorous growth, to reflect the much greater subjection and exposure of the Newton Stewart area to high wind-force than in the eastern areas. Second, that in the Newton Stewart area it attains a luxuriance, density, and height of growth unrivalled in the eastern areas (except on particularly favoured sites) - a luxuriance which must be attributed to the mild winters, high rainfall, and humidity so characteristic of the south-west of Scotland. Further, it has been indicated by both Braid[1] and Conway[2] that a freedom from excessive and prolonged frost allows

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1 Braid, K.W. (1946)

2 Conway, E. (1952)

frond buds to persist throughout the milder winters of the west and encourages rapid growth and expansion at the onset of the growing season. Indeed, given adequate, soil, slope, and shelter, the Newton Stewart area must provide optimum climatic conditions for its growth. Its greater prevalence and more widespread occurrence within this area must be further encouraged, and assured, by the fact that over such a difficult terrain it is rarely cut, except where a labour force such as that employed by the Forestry Commission is available, or attacked as vigorously as it is in places in the Wanlockhead and Peebles areas. While this survey allows a pointer to be made only to the most obvious and explicable contrasts, it is not intended to minimise the seriousness of the bracken problem in these eastern areas where under the destruction of heather and its associated peat layer, its spread at the present is probably moving at a greater speed than in the west.

CHAPTER XV

Summary and Conclusions.

One of the fundamental and indeed basic objectives in attempting these primary-reconnaissance surveys of the Newton Stewart, Wanlockhead, and Peebles areas has been to assess how far the moorland vegetation of the Southern Uplands could, as far as available data allowed, be explained in terms of such purely physical factors as geology, landform, climate and soil - or, expressed in another manner, to what extent such physical factors might be considered to have determined or influenced the establishment and development of the character and distribution of the existing vegetation of the unimproved hill-grazings of this region..... and are continuing to do so. It must, however, always be borne in mind that natural and semi-natural vegetation represents a delicately balanced expression, not only of a complex of closely inter-related physical factors, any one of which may vary in its importance and in its effects from place to place and from time to time and none of which can be easily isolated or its quantity and 'effectiveness' measured satisfactorily, but also, of a complex of biotic factors any of which may fluctuate in intensity even more drastically. In view of such facts it is not possible on the basis of a primary survey alone to hope to attempt more than assess, by a consideration of the nature, form, status, and distribution of the existing vegetation, where and in what respects physical factors appear to play a dominant or important role in determining the type of vegetation, and which of the many, and inter-related, of such factors can be regarded as the most important or effective in any one instance. On the basis of the work that has been undertaken here suggestions, and tentative conclusions, can be offered, but cannot be proved - their only substantiation lies in further corroboration (or invalidation) by more intensive and detailed observation, and finally, by controlled experiment which can aim at, but cannot always succeed in simulating exactly natural conditions.

The results, the deductions - the writer hesitates to call them conclusions, as they cannot be regarded as conclusive - which have emerged from this particular study stem from two sources of slightly different 'status' or 'order'. The first are those presented by the actual study of the moorland vegetation in relation to its particular habitat, or habitats, within each of the individual sample areas surveyed. The second are those which can be deduced from a comparative appraisal of the three sample areas, taken, as they have been, as representative of the Southern Uplands as a whole. Most of these latter conclusions have been intimated, if not necessarily specifically stated, in the course of the preceding descriptions and discussions. They can best be isolated and summarised by considering them under the two suggested headings or 'orders':-

From a consideration of moorland vegetation in relation to particular areas:

The first and most important fact, although one that was to a large extent, in view of the natural history of Britain, a foregone conclusion, but is of such paramount importance in any consideration of moorland vegetation that it is worthy of restatement and re-emphasis - is that very little, if any, of the vegetation within these three areas of Newton Stewart, Wanlockhead, and Peebles, has not been subjected in one way or another (either by grazing, burning, draining, or cutting) to interference by man and his animals, and must, as a result, represent a directly or indirectly modified form of the original climax or sub-climax vegetation. It is an interference and modification, that may have been accelerated by climatic fluctuations, but which has certainly been intensified during the last two hundred years, although it has nevertheless been in progress for an even longer period of time in the Southern Uplands particularly. Also, not only does the moorland vegetation of the Southern Uplands represent a sub-climax which has replaced in many instances a former woodland and/or bog climatic climax, but much, indeed most, of the existing types of moorland are undoubtedly a derivation from, or a much modified form of, a pre-existing type of moorland vegetation, most of which must still to be regarded as in a state of transition or flux. Certainly these modifications have taken place within the framework provided by a set of conditions defined by the physical attributes of a given region, but of the latter only geological structure and land form (in its broadest sense) can be considered to have remained constant throughout the vegetational history of these areas; climate has fluctuated, and soil conditions to an even greater extent under the progressive and accumulative influence of climate and the resulting changes in the vegetation cover.

Only two direct and causal relationships between moorland vegetation and physical factors within any of the three individual areas can be postulated with any degree of certainty. First, to a certain, and generally well-marked, extent the differentiation between, and the distribution of, wet and dry moorland communities (in so far as they can be defined and separated) are dependent basically upon landform, expressed in terms of <u>slope</u> conditions. While there is a close correspondence between the distribution of dry moorland and <u>smooth</u> slopes of over 10° (as is suggested by a comparison of the vegetation maps and the corresponding slope analyses), it would probably be more accurate to say that, under existing climatic regimes, the conditions of free drainage necessary for the establishment and maintenance of dry moorland are assured on smooth unbroken slopes over 20°; in any of the three areas slopes of this degree, or over, always carry some form of dry moorland unless, as is sometimes the case, thick peat, slumping bodily downhill from above, temporarily maintains a wetter vegetation cover. It would, however, be virtually impossible to estimate a critical slope limit (in view of the number of imponderable factors involved) at which the development of wet moorland might be inhibited. Not only would it vary widely according to local and regional climatic conditions, but there can be no certainty as to whether the present slope conditions, which appear to be limiting the development of wet moorland, are fully indicative of the present rainfall conditions. Below an arbitary limit which may, and which would appear to, lie somewhere between 15^{o}-20^{o}, wet moorland becomes prevalent, but its actual extent is dependent more upon the degree of natural and artificial modification that the vegetation has undergone since its initiation; only in the Newton Stewart area is the coincidence between areas of wet moorland and slopes of less than 10^{o}-15^{o} mutually inclusive. Second, the summit vegetation of the Newton Stewart and Wanlockhead areas must be regarded as a climax association determined primarily by the harsher and, above all, exposed climatic conditions of summit ridges and plateaux over 2000' to 2250'.

Apart from these instances the differentiation between often closely related associations within either wet, intermediate, or dry moorland communities - distinctions so often dependent merely upon a slight change in the ratio of the constituent species- is dependent primarily upon, and indeed must be considered as the direct result of, the variations in the duration and intensity of biotic interference and modification, within any one of the three areas .... but nevertheless, intensities of interference and resulting modifications which may, and often are, conditioned, be they ameliorated or accelerated, by the landforms and, in particular, the altitude and slope conditions of the physical sites or assemblage of sites over which they operate.

Within the wet (and also intermediate) moorland communities, altitude appears to play a more important role than variations of slope in the determination of their different constituent associations. However, the general altitudinal zonation of wet associations, revealed in each of the three sample areas, must be regarded predominantly as a reflection of the varying, and generally decreasing, intensity (and duration) of biotic interference and modification with increasing height above, and distance from, the upper limits of cultivation and improvement; and further, the general, but by no means exact, correspondence of the main groups of wet moorland associations with the principal plateau levels - developed to a greater or lesser degree in all three areas at approximately 1000', 1250'/1500' and 1750'/2000' - is primarily a result of the decreasing accessibility of each successively higher level to man and his animals, and also, the ever increasing influence of peaty flushes and seepage from above to which the lower levels are subjected: The latter factor becomes particularly important, and plays an increasingly dominant role in the determination of the nature of the wet moorland vegetation, under conditions of higher rainfall, and also, (as in the case of the 1000' level in the Newton Stewart and the western part of the Wanlockhead area) where the vegetation is subjected to the concentrated, rapid, and abundant run-off from high steep, abrupt slopes above.

On the other hand, the botanical content of the dry moorlands and the development and establishment of either a grass or heather dominated association is dependent largely, and even more closely, upon the intensity of such biotic factors as grazing and burning, the results of which will - assuming that, in any one area, such processes are maintained at equal intensity and regularity throughout - further depend on the degree, aspect, and exposure of the surface slope, with the risk of peat wastage, heather destruction, and soil and slope erosion becoming greater with increasing steepness of slope, with a southerly aspect, and with an increasing exposure to wind. But since, in actual fact, on similar physical sites (as defined in terms of steepness, exposure and aspect) in any one of the three areas the results of their utilisation, or management, may be and generally are reflected in a wide range of vegetation associations and "facies", from pure heather moorland to bare scree-covered slopes, according to the intensity of either grazing or burning and often to the local weather conditions prevailing at the time of interference, it is not surprising that the pattern presented by the dry moorlands is a more random one than for the wet moorland associations. Indeed beyond a recognition of their relationship to slopes allowing a reasonable degree of free drainage it would be impossible to attempt to correlate such "facies" with particular site conditions alone. Nevertheless, the nature and specific content of a dry moorland association may also be influenced, and in some measure determined, by the spatial relation of these favourably drained, steeper slopes to the plateau - levels which may lie above them, the presence, or absence, of which often determines, through the influence of seepage downwards and run-off of water from a peaty or non-peaty area above, whether these steep slopes will maintain (often in face of intensive sheep grazing) a well-defined peaty soil layer and heather, or a predominantly mineral soil, without, or with only an incomplete and poorly developed, peaty layer, and grass. In the case of the former instance, the degree of slope on which the dry moorland association occurs, in influencing and determining the rate of run-off of peaty water from above, may be reflected in the botanical composition of the particular association, and, if seepage and run-off are not excessively rapid, give rise to the appearance of species, such as either Molinia or Nardus, indicative of a higher soil-moisture content.

Within each of the three sample areas investigated, each with its own 'regional' climate, and in each of which geological variations are negligible, or of limited consequence in determining differences of soil, several distinct types of physical 'habitat' or 'site' can be recognised, whose particular and unique characteristics are dependent primarily on <u>landform</u>, expressed in terms of degree (i.e. steep, gentle, or flat) and form (smooth broken, convex, concave, etc.) of surface slope, and altitude - which physical facets Linton would call, 'the ultimate units of relief .... not susceptible to further sub-division on the basis of form"[1] - and whose combination or grouping results in a distinctive <u>pattern</u> of landforms (a reflection of the geomorphological development) in each of the three areas. Such physical facets, with their differing altitudes, aspects and exposure to sun and wind, must possess and be capable of further sub-division on the basis of distinctive 'local' climates. The

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1 Linton, D.L., (1951) p. 209.

difficulty, however, arises in endeavouring to define, delimit and classify such 'sites' - since, apart from altitudes above sea level, their definition is dependent upon attributes such as those presented by climate, for which no instrumental measurements exist, or upon attributes defined in purely relative terms, such as steepness, flatness, roughness and so on. Within these particular sample areas degree of slope is undoubtedly the most important criterion - with regard to the influence it exerts on ruh-off, soil, and vegetation development - by which a distinction can be made between physical habitats or sites. It is one certainly capable of measurement, but offering a bewildering variety and number of site possibilities. If, however, some general criterion of steepness or flatness be accepted (such as has been adopted here of less than 2^{o} flat, 2^{o}-10^{o} gentle (or intermediate), over $10^{o}/20^{o}$ steep) which can be shown, or which appears, to bear some relation to, or influence, some other factor, or factors, inherent in the site, it is possible to recognise <u>and</u> delimit characteristic sites or assemblages of such, each of which will possess certain characteristic potentialities for soil, and vegetation, development - potentialities dependent largely on the influence which the particular site,by way of its slope conditions and local climate, exercises on soil stability and soil moisture.

On this basis, it has been found possible, in any one of the three sample upland areas to define and classify certain physical habitats each with a distinctive 'site', as has been attempted for the Newton Stewart area (see F. 15/16) or distinctive groups or assemblages of sites (physical sub-regions) such as Linton has provided for the Peebles area (see F. 44). A comparison however of the vegetation facets defined in terms of wet, intermediate and dry moorland associations (and represented on the three vegetation maps (F. 12:33:48.) with the physical facets in any one area, reveals that while the pattern of wet and dry moorland vegetation is often closely related to the pattern of landforms dependent upon the grouping of certain similar sites, such as steep slopes or plateau levels, distinctive sites - slopes or flats - which, on the basis of form, can be regarded as generally similar and comparable - do not necessarily carry similar associations since, other factors being equal, soil and vegetation characteristics are determined generally, and finally, by the largely indefinable and immeasurable factor - the degree of intensity, and duration, of the biotic factors operating within, and often modifying or intensifying the effects of, a given set of physical conditions; the result is that in presenting certain possibilities for ecological development sites or habitats which, on the basis of one or more physical criteria, are identical or closely related often carry different associations - associations which are, in fact, often indicative of the genetical stages or status of the same type of vegetation; and, on the other hand, physical habitats or sites which on a similar basis may be capable of differentiation often, due either to the fact that their ultimate effect on soil conditions is similar or because of the action of biotic factors in modifying soil and vegetation conditions carry similar vegetation associations. Only where the vegetation is in a practically natural or relatively unmodified state, as in parts of the Molinia flow and in the summit vegetation, can it be maintained that there is a clearly defined and close coincidence of the limits of vegetation associations and physical habitats or that the dominant factor determining the nature and character of the association is a physical one. And further, it is only in the case of the latter of these two most 'natural' associations within the areas under consideration and which may be regarded as a climatic climax - can it be maintained that the vegetation fully reflects all the inherent possibilities of its physical habitat or site.

The recognition of the distinctive physical sites, each with different ecological possibilities or potentialities, presented by the varied configuration of any part of the earth's surface has been fundamental to the development of modern ecological studies and has, and still is, inherent in the geographer's attempts to define and delimit natural regions on whatever scale. The definition of a 'site', propounded by Bourne as "an area which appears for all practical purposes to provide throughout its extent similar conditions as to climate, physiography, geology, soil and edaphic factors in general".[1] - a definition which might have been made clearer by the use of 'uniform' or 'distinctive' rather than 'similar' conditions - embodies and expands Tansley's

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[1] Bourne, R. (1931) p. 16.

concept of an 'ecotype' as "the particular portion ..... of the physical world that forms a home for the organisms which inhabit it"[1]. The practical application of this concept has largely been developed by the soil scientist as a basis for the classification and comparison of his 'soil types' and by the forester, in his search for a means whereby to assess the silvicultural possibilities of a given area. In the latter respect two attempts to classify sites are worthy of note. First, Bourne[2] - who was originally responsible for developing and applying the concept of 'sites' as an aid, from the forester's point of view, to 'locality assessment' - undertook in 1931 a survey across a strip of country extending from the Chiltern Hills to the London Basin and drew up, on the basis largely of topographical and edaphic considerations, a detailed classification of sites each with certain implied, though not in his survey always clearly defined, ecological characteristics or possibilities. Second, Anderson[3] in 1950, using vegetation as an indication of site conditions, suggested a site classification on an ecological basis in terms of 'plant communities' or 'locality units', applicable to the waste lands of Great Britain and Ireland. Both are attempts to assess the ecological potential of the land on the basis of site classification. They offer different, but what must always be considered complementary, approaches to the same problem; since as Stevens so pertinently reminds us, any

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1 Tansley, A.G., (1949a) p. 228.

2 Bourne, K., (1931).

3 Anderson, M.L., (1950)

particular and individual site, being a resultant of a complex set of factors, it is necessary in its assessment to make as full use of all its indices as possible, and as knowledge permits[1]. Not all these indices, the site factors, and particularly local climate, are easy to measure or assess and, further, since the relative importance and dominance of any of the factors inherent in a given site may vary in ecological importance from place to place, the physical basis for a definition and classification of site may, and must vary also. In the Southern Uplands, and in particular within the three areas which have been surveyed, landform, in view of the influence it exercises on local climate, soil and vegetation, must be considered as the most important site index.

From the plant ecologist's or the geographer's point of view the recognition and definition of physical sites, or groups of sites, on the basis of observed and definable physical conditions allows and facilitates attempts to assess and explain, in terms of either climatic or biotic variations, differences in the botanical character and status of the vegetation (or land utilisation, as the case may be) that occur over sites which may be closely similar or comparable in other (i.e. landform) respects. <u>And</u>, for this reason, although we cannot expect, or even hope to find, in a highly modified type of vegetation, a strict coincidence, or correlation, between plant units and physical sites, <u>must</u> a primary regional survey of vegetation in relation to physical factors (and particularly to landform) be more than justified.

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1 Stevens, H. M. (1938).

Also, it must be regarded as of considerable importance, and assistance, in assessing the influence, by way of the variations in the character and distribution of vegetation, of such otherwise immeasurable factors as climate, man, and his animals in determining, not only the nature and the status of the vegetation, but the potentialities for improvement of hill grazings. Further, as has been found in the course of this study, a consideration of the manner in which any given physical site, or group of sites, and their relative position one to another, may have affected the intensity and the results of man's utilisation and modification of the vegetation they carry, provides a valuable means not only of assessing the relationship of one association to another but provides a basis on which a more realistic grouping of the various facets of the vegetation can be attempted and can be represented in map form.

<u>From a comparison of the vegetation of the Newton Stewart, Wanlockhead and Peebles areas.</u>

It would appear reasonable to conclude that the principal differences such as exist, and as far as it has been possible to analyse and define them, between the vegetation of these three areas arise primarily as a result of certain well-defined climatic differences between the south-west and the north-east of the Southern Uplands - climatic differences which have influenced, and conditioned, the course of the present development of the moorland vegetation in its response to varying intensities of modification, initiated largely by man and his grazing animals, and, to a lesser extent, by natural agencies. Further, the most important and vital of the climatic factors which may, in these upland areas, determine, to a greater or lesser extent, the progressive and accumulative effects of man's interference, and whose regional variations may be responsible for the, albeit minor, differences between otherwise closely similar associations occurring in all three areas, is annual rainfall amount. And, if one looks for one particular feature, association or species, as indicative of existing climatic conditions and its regional variations as exemplified primarily by the progressive decrease in rainfall amount from south-west to north-east of the Southern Uplands, the writer is of the opinion that Molinia caerulea might well be considered to provide just such a climatic index[1]. To no uncertain extent it would appear that it is on the basis of the presence or absence of that species, alone or in association with others, that the most outstanding contrasts, as between associations which in all three areas are often closely related in content and status, are revealed and determined.

Molinia occurs either as a dominant or as a characteristic species in all the most drastically man-modified dry and wet associations within the Newton Stewart and Wanlockhead areas with their high rainfall amounts and with their 'bog-forming' climates, while in the much drier Peebles area, without these limits, it is

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1 Molinia caerulea with its wide range of tolerance of pH and of status is not considered as a reliable site indicator: but in so far as it is dependent on soil moisture conditions it is suggested that it might well reflect rainfall conditions on sites and soils of similar type.

comparatively rare and, above all, restricted in occurrence and is never to the writers' knowledge, completely dominant over wide areas[1]. On the other hand, its close and constant association with Myrica gale in a more characteristically 'bog-vegetation' in the Newton Stewart area serves to distinguish the wetter south-west from the somewhat, but only slightly, less wet climate of the Wanlockhead area. Also, in the latter area Molinia dominated moorland is indicative of a much more advanced stage of peat bog modification, and, in status, and derivation, serves to relate the Wanlockhead to the more eastern Peebles area. However, if it can be assumed, and it seems reasonable to do so, that Molinia moor and Nardus moor may represent homologous stages in peat decomposition in these two respective areas, the difference in specific content may well be attributed to the differences in rainfall (other factors being equal of course) and resulting soil moisture content as between these two areas. The greater preponderance of heather and Eriophorum in their wet moorland associations whether modified by natural or artificial agencies, and of heather in their dry moorland associations serves further to relate the Wanlockhead Peebles areas and to distinguish them from that of Newton Stewart in the south-west where, not only is rainfall higher, but where biotic (and perhaps climatic) modifications have not had such a drastic and advanced effect on

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1 Nevertheless, although this is a plausible and fairly reasonable correlation, the fact cannot be ignored that its poor development in the Peebles area may well be related to the longer and more intense modification of the vegetation by man in this long settled eastern area.

the wet moorland vegetation. The fact that the modifications by natural drainage and erosion of the wet moorlands within the areas surveyed is of negligible significance in the Newton Stewart area, plus the fact that there is a much greater and closer coincidence of wet moorlands to gentle slopes below 10°-15° than in the two eastern areas, may suggest that the principal difference between the three areas arises from the fact that the Newton Stewart area must probably still possess a 'bog-forming' climate, under whose influence either natural or artificial modifications cannot have as drastic and as 'drying' an effect as in the two eastern areas.

Any other direct effects of climate on vegetation form or content are minor and sub-ordinate to those attributable to rainfall, and only in the distribution and extent of summit vegetation in relation to exposed summit climates and the luxuriant response of bracken to the mild temperatures of the south-west, can it be said that regional climatic differences are revealed in the nature of the moorland vegetation.

Landform appears to play a secondary and also a somewhat sub-ordinate role in determining, on a regional scale, the character of the vegetation, but it must be admitted as, nevertheless, an important contributory factor, in so far as it may provide and give rise to characteristically different assemblages of physical sites. If on a climatic basis, reflected in cértain aspects of its vegetation, the Wanlockhead area may reveal certain affinities with that of Newton Stewart or, as it must rather be regarded, be essentially <u>transitional</u> between this latter area and that of Peebles, the very marked differences of site characteristics in the Newton Stewart area dependent on slope characteristics and reflected largely in the areal distributional pattern of the vegetation associations, provides a very clear cut and drastic division between this latter area and that of the two eastern areas whose land-forms and site assemblages are so closely comparable. Indeed, in this latter respect, it is a distinction so clearly marked that one of Hardy's concluding observations to his study of the vegetation of the Highlands of Scotland, that "les hautes terres d'Éccosse sont divisées par le climat, la topographie et la végétation ainsi que par leur influence combinée sur l'homme, en deux domaines: le domaine occidental est pluvieux et plus avancé dans l'évolution modelé. C'est aussi un pays de pâturages de montagnes et de prairies mouilleuses dans les fonds. Le chêne jusqua'a 300m. et l'épicéa de Norvege plus haut, seraient sa vocation naturelle. Le pin sylvestre y vient moins bien. Le domaine oriental plus sec et aussi moins découpé par l'erosion. La végétation actuelle consiste en majeure partie en bruyères, landes herbeuses seche et forêts (pineraies et mélézins). L'étendue des plateaux et terrasses permet un grand développement de tourbières de montagnes"[1], would be, in many respects, just as applicable to the Southern Uplands of Scotland, and provides a similarly and singularly fitting summary and conclusion to this study.

Postscript: The objectives, together with the 'exploratory'

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[1] Hardy, Marcel, (1905) p. 174.

nature of these surveys, have been such that more problems have been raised and more hypotheses suggested than have been adequately elucidated. This study cannot, therefore, be regarded as a self-contained, conclusive piece of work, but rather, as the completion of a stage which must, if it is to be of any real value, be followed by either a more intensive and detailed study of the individual sample areas and their plant associations on the one hand, or, on the other, by the application of the methods of regional vegetation survey which have been outlined to an even wider area, such as the whole of the Southern Uplands. The author considers that the two most important problems, worthy of further investigation, to which this work points are:-

-1.) The further development of the concept of 'sites'__ their definition and classification, and, in particular, of those which can be defined in terms of landform ---not so much as a means of classifying and mapping vegetation as of assessing the influence and effects of varying intensities of, as yet, imponderable factors, be they climatic or biotic, in the determination of vegetation and soil types.

-2.) The more detailed study of the possibilities which Molinia caerulea may, in upland grazings, offer as a climatic index with, if such is the case, a sharper definition of its critical limits.

In both these problems, the broad regional, as against the local intensive, survey must play a basic and fundamental part, especially if , as it seems, there is still as much to be learnt from qualitative comparisons and correlations, as from quantitative measurements and analyses. And as a basis for what are considered vitally necessary regional comparisons, the primary vegetation survey is more than justified and warrants more attention than has been accorded it of late. Indeed, it offers a particularly attractive and promising field in which the plant ecologist, the soil scientist, and the geographer could, more than usefully, pool their resources to the benifit, as well as to the academic interest, of themselves and the agriculturalist.

Appendix.

NEWTON STEWART AREA — Statistical Abstracts from the Climatological Atlas of the British Isles.

		J	F	M	A	M	J	J	A	S	O	N	D	Year
TEMPERATURE °F 1901-1930	Av. Means Daily Max.	44/45	45	47	52	59	64	66	64	61	55	48	45	54
	Av. Means Daily Min.	36/35	35	35	38	43	47	51	51	47	43/44	38	36	42/41
	Av. Means Daily Mean	40	40	41	45	51	55	58	57	54	49/50	43/44	40	48
	Av. Annual Max.	.	.	.	.	.	.	.	.	.	.	.	.	75-80°
	Av. Annual Min.	.	.	.	.	.	.	.	.	.	.	.	.	20-15°
	Absolute Max		.	.	.	.	.	.	.	.	.	.	.	85-90°
	Absolute Min		.	.	.	.	.	.	.	.	.	.	.	5°
	Av. Date of: (1911-40) 1. First Screen Frost				.	.	.	.	.	.	1st-15th			
	2. Last Screen Frost				.	1st-15th								
	Average annual frequency of days per year with (1913-40) (1) Max. Temp. 78°F+......1 (2) Max. Temp. 32°F-......2-5 (3) Min. Temp. 32°F-......50-100 (4) Min. Temp. 60°F+......1 or less													

NEWTON STEWART AREA Statistical Abstracts from the Climatological Atlas of the British Isles.

		J	F	M	A	M	J	J	A	S	O	N	D	Year
SNOW (1912-1938)	1. Av. No. of days with snow falling on low ground (0-200') in winter months	4	2	3	1	0	0	0	0	0	0	0	2	15-20
	2. Av. No. of mornings with snow lying in winter months	2/5	2/5	2/5	1	0	0	0	0	0	0	1/2	2/5	10-30
SUNSHINE (1901-1930)	Av. Means of Daily Duration of bright Sunshine	1	2	3.5	5	6	6.5	5	4.5	4	3	2	1	3.5 hrs.
	Av. Means of Percentage of Possible bright Sunshine	15	20	30	35	35	35	30	30	30	25	20	15	30%
HUMIDITY (1921-1935)	Av. Means of Vapour Pressure	8	8	8	8	10	12	14	14	12/13	10/11	8/9	8	10m.b.
	Av. Means of Rel. Humidity	85	80	75	70	70	70	70	75	75	75	80	85	75%
	Av. Means of Saturation Deficit	1.5	1.5	2	3/4	5	6	6	5	4/5	3	2	1.5	3m.b.
RAINFALL (1901-1930)	Av. R'F.	6	4/5	4/5	3/4	3/4	3	4	4/5	4	6/7	6/7	6/8	40/80 INS.
	Av. No. of Rain days	23	17	20	17	17	14	17	20	17	20	20	23	225 DAYS
	Greatest No, of Consecutive days without measurable rain ... 30 Greatest No. of Consecutive days with measurable rain ... 50													1903-1940
WIND (1926-40) (1918 -37)	A v. Wind Speed....12.5m.p.h. Av. Annual No. days with gale....10 days.													

NEWTON STEWART AREA

CLIMATIC STATISTICS

		J	F	M	A	M	J	J	A	S	O	N	D	Yr.
CALLY (120') 1881-1915 (Book of Normals)	Rainfall (INS.)	4.4	4.0	3.8	2.9	3.2	2.9	3.5	4.6	3.8	4.7	5.1	5.5	48.8
	Max. Temp. °F.	42.9	44.1	47.1	52.5	58.3	63.5	65.1	63.7	60.1	53.9	47.9	44.0	53.6
	Min. Temp. "	33.7	33.3	34.1	36.6	41.3	46.7	49.0	48.4	45.4	40.4	36.5	34.3	40.0
	Mean Temp. "	38.3	38.1	40.6	44.6	49.8	55.1	57.1	56.1	52.8	47.2	42.2	39.2	46.8
1856-1895 (Buchan 1898)	Mean Temp. °F.	38.7	39.0	40.6	45.8	50.4	55.5	57.7	56.7	53.9	47.3	42.0	39.2	47.2
Weather No. of days 1914-1919 (E'burgh Met. Office)	Snow	.5	2.1	3	1.3	0	0	0	0	0	.5	.8	2.0	12.5
	Snow Lying	1.1	.8	1.7	.5	0	0	0	0	0	.1	.8	2.3	10.0
	Ground Frost	.	.	.	.	.	.	.	.	.	.	.	.	.
	Gale > 8	.5	.6	.1	0	0	0	0	0	0	.3	.5	.5	2.6
KIRKCOWAN (140') (1920-1949) BRITISH RAINFALL.	Rainfall (INS)	5.7	3.5	3.5	2.7	3.0	4.0	4.2	4.1	5.7	5.6	5.6	5.6	51.1
(1856-1895) (Buchan)	Mean Temp. °F.	38.3	38.7	40.3	45.5	50.0	55.0	57.8	56.6	54.0	47.2	41.6	39.2	47.0
DALRY (250') 1903-1937 (Br. Rainfall)	Rainfall (INS.)	5.7	4.5	2.7	2.5	3.2	2.6	3.6	4.1	3.3	5.1	5.0	6.3	51.0
GARLIESTON (30') (1903-1943) (Br. Rainfall)	Rainfall (INS.)	3.3	3.3	3.2	2.2	2.4	2.2	2.5	3.5	2.0	4.6	3.7	4.7	35.4

NEWTON STEWART AREA (contd.) CLIMATIC STATISTICS

		J	F	M	A	M	J	J	A	S	O	N	D	Yr
WHITHORN (200') (1918-1935) (Br. Rainfall)	Rainfall (INS)	4.2	2.7	2.3	2.0	2.7	2.4	3.0	3.9	3.7	4.7	4.1	4.8	40.9
GLENLEE P.S. (181') 1937-1949	Rainfall (INS)	7.3	4.9	3.9	3.3	3.3	4.0	4.1	3.9	5.0	6.0	6.7	6.4	58.8
(Edinburgh Met. Office)	Max. Temp. °F	42.1	44.2	48.4	49.1	59.7	64.5	65.8	66.4	61.6	55.0	49.1	44.6	54.6
	Min. Temp. "	30.7	32.8	34.0	38.3	40.8	46.7	57.2	49.6	47.0	41.2	36.8	36.2	40.1
	Mean Temp. "	36.4	38.5	38.3	46.2	50.4	55.6	58.0	57.4	54.3	48.2	42.9	39.0	47.4
Weather No. of days	Snow	7.7	5.4	5.0	.7	.2	0	0	0	0	.1	1.0	3.5	24.0
	Snow Lying	5.5	4.0	1.9	0	0	0	0	0	0	0	0	2.2	12.0
	Ground Frost	17.2	11.6	11.9	10.0	8	1.3	0	.4	0	6.4	13.2	14.1	79.0
	Gale > 8	.3	.6	.1	.2	0	0	0	0	0	.2	.3	.3	2.4
GLENLEE (206') 1856-1895 (Buchan)	Temperature (MEAN) °F	37.6	38.6	39.9	45.1	49.9	55.6	57.8	56.8	53.5	46.8	40.7	38.6	46.7
NEWTON STEWART (75') 1939-1943	Rainfall (INS)	5.3	3.8	3.6	2.2	2.6	1.5	5.0	3.6	4.0	5.4	5.6	4.9	47.7
	Max. Temp. °F	40.2	43.6	47.5	52.7	59.7	65.9	63.7	64.2	61.9	54.3	49.0	43.5	53.7
E'burgh Met. Office	Min. Temp. "	30.1	32.4	34.5	38.8	41.8	47.5	50.5	50.8	47.1	41.3	36.0	34.1	40.1
	Mean Temp. "	35.1	38.0	41.0	45.7	50.5	56.7	56.9	57.5	54.5	47.8	42.5	41.0	46.9
Weather No. of days	Snow	5	2	2	.4	.4	0	0	0	0	.2	.2	1.2	10.2
	Snow lying	5.2	3.2	1	.4	0	0	0	0	0	0	0	.8	10.6
	Ground Frost	.	.	.	.	.	.	.	.	.	.	.	.	.
	Gale > 8	.2	.2	.2	.2	0	0	0	.8	0	.2	.8	.2	3.2

WANLOCKHEAD AREA

Statistical Abstracts from the Climatological Atlas of the British Isles.

		J	F	M	A	M	J	J	A	S	O	N	D	Year
TEMPERATURE °F 1901-1930	Av. Means Daily Max.	44	44	47	52	59	63	66	64	61	55	47	44	54
	Av. Means Daily Min.	34	34	34	37	42	46	50/51	50/51	46	43	37	35	41
	Av. Means Daily Mean	39	39	41	45	51/50	55	58	57	53	48	42	40	47
	Av. Annual Max.	.	.	.	.	.	.	.	.	.	.	.	.	75°+
	Av. Annual Min.	.	.	.	.	.	.	.	.	.	.	.	.	15-20°
	Absolute Max	.	.	.	.	.	.	.	.	.	.	.	.	85°+
	Absolute Min	.	.	.	.	.	.	.	.	.	.	.	.	0°-
	Av. Date of:- (1911-1940) 1. First Screen Frost									15th ←	→ 1st			
	2. Last Screen Frost			15th ←	....	....	→ 1st							
	Av. Annual Frequency of Days per Year with (1) Max. Temp. 78°+......1+ (2) Max. Temp. 32°-......1-5 (3) Min. Temp. 60°F+.....1- (4) Min. Temp. 32°-......100													

WANLOCKHEAD AREA — Statistical Abstracts from the Climatological Atlas of the British Isles.

		J	F	M	A	M.	J	J	A	S	O	N	D	Year
SNOW (1912-1938)	Av. No. of days with snow falling on low ground (0-200') in winter months	4/5	4	4	2	.	.	.	.	.	.	1	3	25
	Av. No. of days with snow lying in winter months of the year	5	5	5	2	.	.	.	.	.	.	2/5	5	20-50
SUNSHINE (1901-30)	Av. Means of daily duration of bright sunshine	1	2	3.5	4.5	5.5.	6	5	4	4	3	2	1	3.5 hrs
	Av. Means of percentage of possible bright sunshine	15	20	30	30	35	35	25	25	30	25	20	15	30%
HUMIDITY (1921-35)	Av. Means of Vapour Pressure	8	7/8	8	8	10	12	14	14	12	10	9	8	10 m.b.
	Av. Means of Rel. Humidity	85	80/75	70	70	65	65	70	70	70/75	75	80/75	85	75%
	Av. Means of Sat. Deficit	1.5	2	2/3	4	5	6	6	6	5	3	2	1.5	3/4 m.b.
WIND (1926-40) (1918-37)	Av. Wind Speed .... 12.5 - 10 m.p.h. Approx. Av. Annual No. of days with gale........... 10 days.													
RAINFALL (1901-30)	Av. Rainfall ~~days~~	8	6	4/6	4	3/4	3/4	4	6	4	6	6	8	50/60 (INS.)
	Av. No. rain days	23	17	20	17	17	14	17	20	17	20	20	23	225 (days)

WANLOCKHEAD AREA

CLIMATIC STATISTICS

		J	F	M	A	M	J	J	A	S	O	N	D	Yr.
DRUMLANRIG (160')														
1881-1915 (BOOK OF NORMALS)	Rainfall (INS.)	3.0	3.0	2.8	2.2	2.5	2.3	3.0	3.8	2.5	3.7	3.4	4.0	36.8
1856-1895 (Buchan)	Temperature (MEAN) °F.	37.4	38.3	39.8	45.3	49.9	55.6	57.9	56.9	53.6	46.9	40.8	37.8	46.7
DOUGLAS (783')														
1927-1935 (Br. Rainfall)	Rainfall (INS.)	6.3	3.0	2.6	2.8	2.3	3.3	3.0	3.5	3.2	5.8	4.3	4.7	42.7
1856-1895 (Buchan)	Temperature (MEAN) °F.	35.8	36.8	38.2	43.1	47.6	53.8	56.0	55.5	51.6	44.5	39.3	36.5	44.9
MOFFAT (400') (Auchenlas) 1910-1923 (Br. Rainfall)	Rainfall (INS.)	5.7	5.4	3,6	3.1	3.1	2.4	3.8	5.1	3.1	4.9	4.9	6.9	50.2
LEADHILLS (1310')														
1901-1920	Rainfall (INS.)	8.2	6.4	5.4	4.9	4.2	3.2	5.0	6.8	4.6	6.2	5.7	8.2	69.8
1914-1927	Rainfall "	9.2	6.6	5.3	4.7	4.4	3.1	5.2	7.1	5.7	6.5	6.2	7.6	72.3
1914-1927 Max. °F.	Temperature	39.9	39.8	42.1	47.6	55.9	59.1	61.8	60.5	55.6	50.	42.7	39.1	49.4
Min.		30.1	31.0	29.5	30.9	38.4	42.3	46.7	46.5	42.4	38.0	31.4	30.4	36.1
Mean		35.0	35.0	35.7	40.0	46.4	50.7	54.3	53.5	48.8	44.0	36.8	35.1	43.0
Weather No. of days 1914-1927	Snow	8.0	8.9	9.3	4.3	2.0	0	0	0	.4	1.5	3.7	8.2	47.0
	Snow lying	11.4	12.1	9.0	3.4	1.1	0	0	0	0	1.0	7.0	11.0	61.0
	G. F.	.	.	.	.	.	.	.	.	.	.	.	.	.
(Edinburgh Met Office.)	Gale > 8	2.3	1.5	.7	.4	0	.5	0	0	.4	.8	2.9	1.6	13.2
WANLOCKHEAD (1334') 1856-1895 (Buchan)	Temperature (MEAN) °F.	33.2	34.2	35.2	40.1	45.5	51.6	54.1	53.8	49.7	43/2	37.2	34.0	42.7

PEEBLES AREA

Statistical Abstracts from the Climatological Atlas of the British Isles

		J	F	M	A	M	J	J	A	S	O	N	D	YEAR
TEMPERATURE °F. (1901 – 1930)	Av. Means Daily Max.	44	45	47/48	52	58	64	66/67	65/66	61	54/55	47	44	54
	Av. Means Daily Min.	34	33	34	36	42	46	50	50	46	41	36	34	40
	Av. Means Daily Means	39	39	41	45	50	55	58	57	54	48	42	39	47
	Av. Annual Max.	.	.	.	.	.	.	.	.	.	.	.	.	75+
	Av. Annual Min.	.	.	.	.	.	.	.	.	.	.	.	.	10–15
	Absolute Max	.	.	.	.	.	.	.	.	.	.	.	.	85+
	Absolute Min	.	.	.	.	.	.	.	.	.	.	.	.	0^{+}_{-}
	Av. Date of (1911–40) 1. First Screen Frost									15th..	.1st			
	2. Last Screen Frost					15th								

Average Annual Frequency of days per year with

1913–1940

(1) Max. Temp. 78°+......1+
(2) Max. Temp. 32°-......2-5
(3) Min. Temp. 60°+......1-
(4) Min. Temp. 32°-......100

PEEBLES AREA

		J	F	M	A	M	J	J	A	S	O	N	D	Yr.
SNOW (1912-38)	Av. No. days with snow falling on low ground (0-200')	5	4	5	2	.	.	.	.	.	.	1	4	30
	Av. No. of mornings with snow lying in winter months of year	10	10	5/10	2	.	.	.	.	.	.	2/5	10	20-50
SUNSHINE (1901-1930)	Av. Means of daily duration bright sunshine	1	2	3.5	5	5.5	6	5	4.5	4	3	2	1	3.5hrs
	Av. Means of percentage possible bright sunshine	15	20	25	35	35	35	30	30	30	25	25	15	30%
HUMIDITY (1921-1935)	Av. Means of Vapour Pressure	8-	8-	8-	8	10	12	14	14	12	10	9	8	10 mb.
	Av. Means of Relative Humid.	85	80-	70/75	70	65	65	70	70	70	75-	80-	85	75 %
	Av. Means Sat. Deficit	1.5	2	3/2	4/3	5	6	7	6	5	3	2+	1.5	4 mb.
RAINFALL (1901-30)	Av. Rainfall	3	3	3	2	2/3	2	3	4	3/2	4	3/4	4	40 (INS.)
	Av. No. Rain Days	20	17	17/20	17	17	14	17	20	17/14	20	20/17	20	225(days)
(1903-40)	Greatest No. of consecutive days without measurable rain ... 30+ Greatest No. of consecutive days with measurable rain ... 30-40													
WIND (1926-40)	Av. Wind Speed .... 12.5 (approx.) mph.													
(1918-37)	Av. Annual number days with gale .... 10 days.													

PEEBLES AREA

CLIMATIC STATISTICS

		J	F	M	A	M	J	J	A	S	O	N	D	Yr
SELKIRK (450') 1903-1919 (Br. Rainfall)	Rainfall(INS.)	2.9	2.8	3.2	1.4	2.4	1.5	2.5	3.5	1.7	3.8	2.8	3.7	33.9
STOBO CASTLE (594') 1908-1949 (Br. Rainfall)	Rainfall(INS)	4.1	2.9	2.6	2.3	2.5	2.3	2.9	3.4	3.0	3.8	3.6	4.0	38.4
1856-1895 (Buchan)	Temperature (MEAN) °F.	35.7	36.9	38.5	43.4	48.6	54.6	56.7	55.9	51.9	45.3	39.4	36.3	45.3
EDDLESTON PORTMORE (1000') 1903-1907 (Br. Rainfall)	Rainfall(INS.)	2.7	2.4	2.8	1.9	3.2	2.1	2.6	5.5	1.7	5.7	3.3	2.3	36.2
GLADHOUSE RES. (750') 1936-1949 (Br. Rainfall)	Rainfall(INS)	3.7	2.7	2.7	1.8	2.6	2.2	3.7	2.9	2.7	3.3	3.5	3.0	36.3
N. ESK RES. (1150') 1856-1895 (Buchan)	Temperature (MEAN) °F °F.	34.2	35.3	36.1	40.8	45.9	52.2	54.5	54.1	50.5	43.9	37.9	34.9	43.4
ETTRICK MANSE (787') 1920-1928 (Br. Rainfall)	Rainfall(INS)	8.6	5.1	4.8	3.7	4.7	2.9	4.5	6.1	4.6	6.1	5.0	6.2	63.2

PEEBLES AREA (contd.)

CLIMATIC STATISTICS

		J	F	M	A	M	J	J	A	S	O	N	D	Yr
EDINBURGH WATER WORKS (Victoria Lodge)(900') 1929-1949 (Br. Rainfall)	Rainfall (INS.)	5.6	3.3	2.9	2.9	2.8	3.0	3.4	3.5	3.6	5.5	5.1	5.5	48.4
GALASHEILS (450') 1921-1931 (Br. Rainfall)	Rainfall (INS.)	3.4	2.7	2.1	2.0	2.5	2.3	2.9	4.6	3.0	3.6	3.2	3.1	36.3
1856-1895 (Buchan)	Temperature (MEAN) °F.	36.5	37.3	39.1	43.6	48.4	54.0	56.9	56.2	52.3	45.7	40.0	37.2	45.6
PEEBLES (525') 1934-1938) 1942-1946)	Rainfall (INS.)	3.4	2.6	1.8	1.8	2.0	2.4	2.7	2.9	2.8	3.9	2.9	3.2	32.9
(Edinburgh Met Office)	Max. Temp. °F	42.0	43.8	47.2	52.3	57.4	62.5	65.5	65.3	60.4	53.9	46.8	43.5	53.3
	Min. Temp. "	30.6	32.5	33.7	36.1	39.2	45.6	44.9	48.9	45.8	40.2	35.2	32.4	39.0
	Mean Temp. "	36.3	38.2	40.5	44.1	48.3	54.2	57.5	57.3	52.8	47.1	40.9	38.1	46.2
(PEEBLES) THE GLEN (765') 1856-1895 (Buchan)	Temperature (MEAN) °F.	35.0	36.2	37.6	42.3	47.8	54.4	56.4	56.0	51.7	45.0	38.7	35.8	44.7
Weather (PEEBLES 525') No. of days (Edinburgh Met. Office.)	Snowfall	10	7.6	5.5	2.1	1.0	0	0	0	0	.6	2.5	4.2	34.5
	Snow Lying	9.7	5.7	5.0	.1	0	0	0	0	0	0	.1	1.6	24.5
	G.F.	18.6	14.5	14.2	8.6	7	.8	0	.5	2.0	6.6	11.1	14.3	86.1
	Gale	.2	1.3	.2	.8	0	.1	0	0	.5	0	.5	.3	4.3
Hrs. sunshine		28.1	65.1	100.1	137.2	187.6	156.9	145.8	122.8	103.9	75.8	42.8	22.9	1184.2 hrs
% Possible sunshine		11.7	24.7	27.3	32.6	37.6	30.1	28.0	26.5	24.5	23.5	18.3	10.6	26.5 %
WEST LINTON (820') 1908-1935	Max. Temp. °F	41.2	41.7	44.3	49.1	55.8	61.1	63.7	62.4	58.0	51.8	44.5	41.8	51.3
AV. OF. TEMP. FOR PERIODS ENDING 1935 BR. ISLES.	Min. Temp. "	30.3	30.8	31.0	33.5	38.7	43.3	47.4	46.7	42.2	38.1	32.5	31.5	37.2
	Mean Temp. "	35.7	36.3	37.7	41.3	47.3	52.2	55.5	54.5	50.1	44.9	38.5	36.7	44.3

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